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APOLLO 17: THE FINAL LUNAR LANDING & ITS LEGACY

#211 DECEMBER 2022

Sky at Night

THE UK'S BEST-SELLING ASTRONOMY MAGAZINE

MARS MEETS THE MOON

Watch the Red Planet disappear behind the Moon this month

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25 SIGHTS FOR CHRISTMAS

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Welcome

Scopes, binoculars, cameras! Mars is ready for its close-up

If, like me, you've been eagerly watching Mars improve in appearance over the past few months, you'll be excited that December is here. It really is the month of Mars: not only is the Red Planet at its closest to Earth and at opposition this month – putting it at its brightest and largest for observing – but on the same date as opposition it will also briefly vanish behind the Moon. This event, a lunar occultation, is rare, so set your alarms early! For all the details, turn to the Sky Guide on **page 46**. You'll also find a guide to photographing this exciting meeting of Mars and the Moon on **page 76**. But Mars is well-placed in the night sky all month and well into 2023, so read our feature on **page 35** to discover how to maximise this special Mars season.

This month also marks the 50th anniversary of the launch of Apollo 17, the final Apollo mission and the last time humans set foot on the Moon. We've got a blow-by-blow account of this record-breaking mission on **page 62**, while on **page 66** we consider the rich legacy left by the whole Apollo programme. Its imprint is to be found on scientific research and crewed spaceflight up to this day – and of course is keenly felt with the imminent launch of Artemis I.

Lastly, there's the chance to win a £250 Amazon gift voucher when you tell us what you think about the magazine. To share your views, just visit **bbcstudios.com/survey** to take part – it takes less than 10 minutes to complete.

Enjoy the issue, and season's greetings!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 15 December.

HOW TO CONTACT US

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Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18

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Visit our website for competitions, astrophoto galleries, observing guides and more

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Follow us on Twitter, Facebook and Instagram for space news, astro images and website updates

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The best targets to observe each week, delivered to your inbox. Visit **bit.ly/skynewsletter**

Find out more at: www.skyatnightmagazine.com

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The Sky Guide

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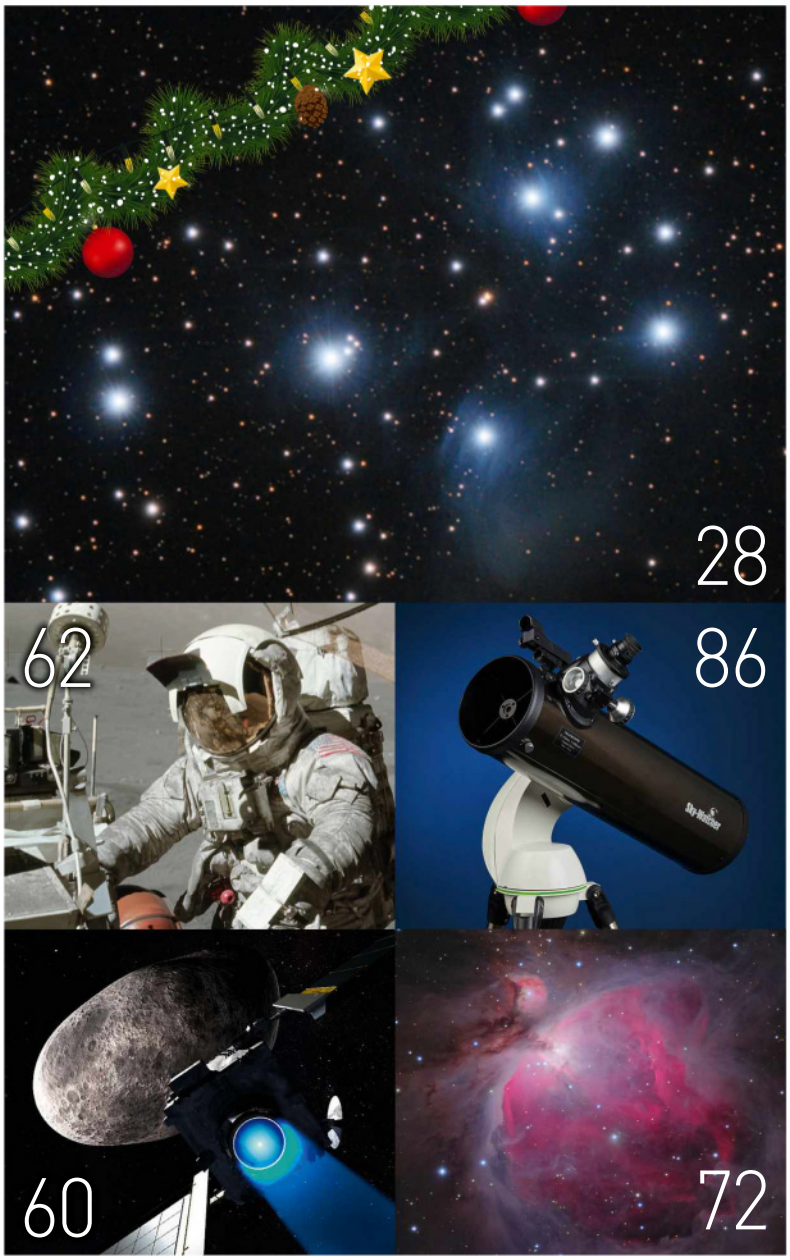
New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**



This month's contributors

Stuart Atkinson

Seasoned observer

"Planets, nebulae, galaxies, stars: there's going to be so much to see in the night sky this December, we're in for a treat". **Turn to page 28, where Stuart reveals his top 25 night-sky sights for the run-up to Christmas**

Charlotte Daniels

Astronomy journalist

"Mars is easy to spot and beautiful to view in the right conditions, so getting the chance to see it at its best is always a highlight!" **Charlotte tells us how to get the maximum out of Mars season on page 35**

Ezzy Pearson

Features editor

"It's been fascinating covering the Apollo programme, and none more so than the final mission. The science-packed expedition is still revolutionising planetary science 50 years later." **Travel back to Apollo 17 with Ezzy on page 62**

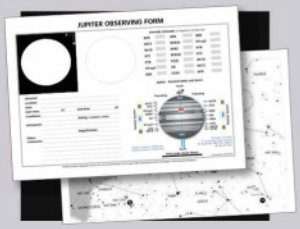
Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/PF5NNHB** to access this month's selection of exclusive Bonus Content

DECEMBER HIGHLIGHTS

Interview: Apollo 17, behind the scenes

Dermot Gethings attended the launch of the last mission to the Moon. He reveals his first-hand view of the event.



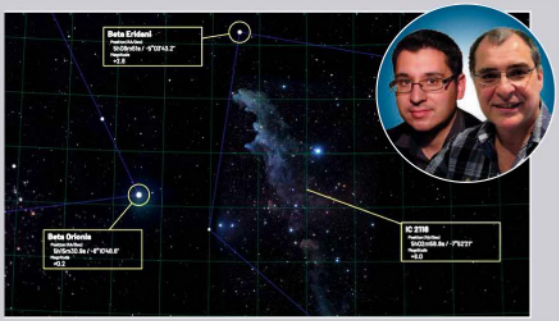
Watch *The Sky at Night: Question Time*

In this episode of *The Sky at Night*, filmed in front of a live audience, the team and guests tackle your queries about the cosmos.

Observing forms and deep-sky tours

Download extra materials including observing forms, deep-sky tours and astronomy software that will guide your mount.

The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

CREATION AND DESTRUCTION

Webb recreates a classic Hubble image in stunning new detail

JAMES WEBB SPACE TELESCOPE, 19 OCTOBER 2022

The Pillars of Creation, part of the Eagle Nebula in Serpens, look incredible in this new image captured by the James Webb Space Telescope. Made famous in 1995 by Webb's forebear, the Hubble Space Telescope, the pillars are made of molecular hydrogen and dust, filled with protostars.

We see them from a distance of 7,000 lightyears, but the left-hand pillar is four lightyears long; the apparently tiny protrusions at its tip are actually larger than our Solar System. The pillars have been eroded into their distinctive shapes by the ultraviolet light from nearby newly formed stars, in a process known as photoevaporation.

Sadly, the pillars were probably destroyed 6,000 years ago by a supernova, the shockwave from which can be seen approaching the formation in images from the Spitzer Space Telescope. This interpretation has been challenged by other scientists, but we won't know for sure for another 1,000 years.

NASA/ESA/CSA/STSCI/J. DEPASQUALE/A. KOEKEMOER/A. PAGAN (STSCI)

△ Baby boomer

HUBBLE SPACE TELESCOPE, 21 OCTOBER 2022

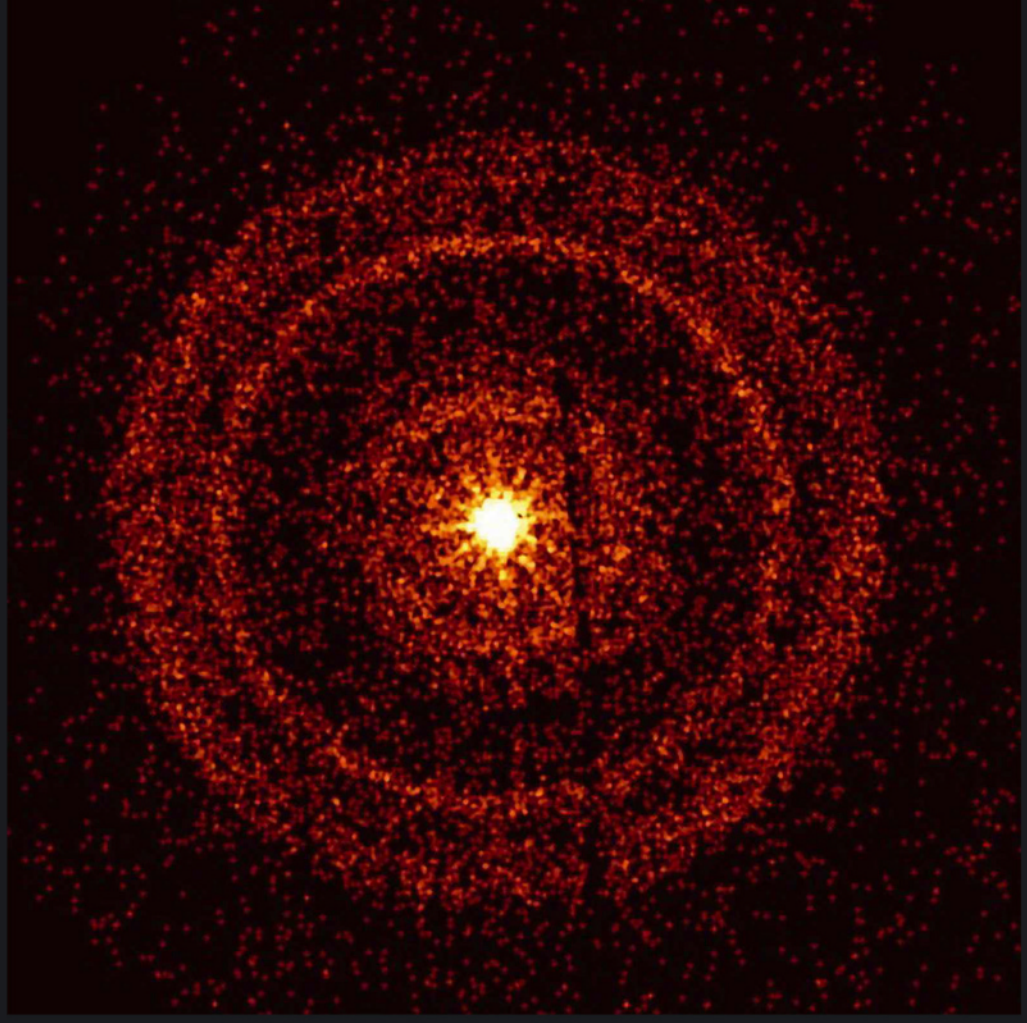
Patches of nebulosity associated with the birth of stars, Herbig–Haro objects are commonly found in star-forming regions after new stars send out jets of ionised gas. Here, Hubble's Wide Field Camera 3 focused on HH1 and HH2, two Herbig–Haro objects lurking in the constellation of Orion, about 1,250 lightyears from Earth. Parts of the gas cloud are moving at more than 400km/h and the star that formed them is actually in the centre of the image, hidden behind clouds of dust.

The ice moon cometh ▷

JUNO, 5 OCTOBER 2022

Europa, smallest of the Galilean moons of Jupiter, displays its fractured, icy surface in this image taken from an altitude of around 412km above the frozen moon. The picture was taken with the Juno probe's Stellar Reference Unit, a camera usually used to orientate the spacecraft using the stars. Despite only producing a black and white image, it has excellent low-light sensitivity – this photo was actually taken at night, illuminated by light reflected from Jupiter's clouds.

ESA/HUBBLE & NASA/B. REIPURTH/B. NISINI, NASA/JPL-CALTECH/SVRI, NASA/SWIFT/A. BEARDMORE (UNIVERSITY OF LEICESTER), X-RAY: NASA/CXC/DURHAM UNIV./G. MAHLER/IR: NASA/ESA/CSA/STSCI



◁ X-ray afterglow

NEIL GEHRELS SWIFT OBSERVATORY, 13 OCTOBER 2022

Gamma-ray bursts are some of the most energetic and mysterious events in the Universe, huge amounts of energy likely to have been produced when black holes are born. This pulse of energy, known as GRB 221009A, came from a point 1.9 billion lightyears away in the constellation Sagitta. The burst was first detected by NASA's Fermi Gamma-ray Space Telescope, which saw it shine like a beacon for 10 hours. Swift's X-ray telescope was able to capture this afterglow.

MORE ONLINE
Explore a gallery of these and more stunning space images

Kind of blue ▷

JAMES WEBB SPACE TELESCOPE & CHANDRA X-RAY OBSERVATORY, 4 OCTOBER 2022

Two telescopes combine for this deep-field image, Webb providing the infrared data and Chandra adding an X-ray view. There's a lot going on here in galaxy cluster SMACS J0723, 4.2 billion lightyears away in the constellation of Volans, with foreground stars made notable by their diffraction spikes; background galaxies heavily lensed; and the blue glow of gas, with a mass of about 100 trillion times that of the Sun, heated to millions of degrees and radiating X-rays.

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The Widescreen Centre

News & Events Autumn 2022

Autumn skies are back with us. Whether you're still capturing summer DSOs or planning ahead to targeting the winter constellations and the spectacular array of planets, here at The Widescreen Centre we're ready with an amazing range of in-stock, ready to go, telescopes, mounts and accessories - and advice - to enable you to get the most out of your observing time. Call or email us for advice and the best package deals around. *sales@widescreen-centre.co.uk* or call us on (01353) 776199 10-4 Monday to Friday.

Equinox Star Party time! See us at Kelling Heath, NR25 7HW Saturday September 24th See www.las-skycamp.org

The International Astronomy Show is back! And so are we. See us at IAS 2022, booth 12! October 14th & 15th CV8 2LH See www.ukastroshow.com

Visiting The Widescreen Centre

Current plans are for our Cambridgeshire showroom to reopen *on an appointment only basis* later in October. See our website for details, sign up for our Newsletter or just call on one of the numbers below.

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The latest astronomy and space news, written by Ezzy Pearson

BULLETIN

The first direct observation of concentric dust rings around a star, sculpted by radiation pressure from its light

NASA/ESA/CSA/STSCI/JPL-CALTECH

Stellar smoke rings shaped by starlight

Strange structure is first time light is seen actively sculpting cosmic dust

Back in July this year, astronomers were baffled by the discovery of 17 concentric rings around a binary star system, WR140, in images taken by the James Webb Space Telescope. Though some wondered if it could be signs of an alien megastructure, recent simulations have found that the most likely explanation is dust blown out from a dying star being sculpted not just by stellar winds, but by the push of starlight – the first time the latter has been seen as it is happening.

WR140 is a blue supergiant star orbited every eight years by a Wolf–Rayet, a dying star with extremely strong winds. When the pair get close, the Wolf–Rayet star briefly produces dust that is then pushed outwards by stellar winds.

"Eight years later, as the binary returns in its orbit, another ring appears, the same as the one before, streaming out into space inside the bubbles of the previous one, like a set of giant nested Russian dolls," says Peter Tuthill from the University of Sydney, who took part in the study.

However, the pattern of rings only matches their simulations precisely when they included not just the solar wind, but the push of starlight on the dust. Though the after-effects of this 'radiation pressure' have been seen many times, this is the first time that it has ever been directly observed.

"When it catches the photon wind streaming from the star, like a yacht catching a gust, it makes a sudden leap forward," says Tuthill. "In one sense, we always knew this must be the reason for the outflow, but I never dreamed we'd be able to see the physics at work like this."

webb.nasa.gov

Comment

by Chris Lintott

Since their discovery back in the 19th century, astronomers have wondered how Wolf–Rayets fit into the lives of stars. They're thought to be produced when the most massive blue stars use up their hydrogen fuel, and have long been blamed for many Type 1b and 1c supernovae. But nagging doubts remained. We'd simply never seen an explosion that looked like it had been affected by the material we see surrounding Wolf–Rayets like WR140. But earlier this year Israeli astronomers showed that supernova 2019hgp took place inside a nebula like WR140's. While it's too early to say that WR140 will definitely end its life in a bang, we now know at least one of its cousins did.

Chris Lintott co-presents *The Sky at Night*

▲ **The Boeing 747 will release a 21-metre satellite-bearing rocket (inset) into low-Earth orbit after takeoff from Spaceport Cornwall**

First space launch from UK soil

Virgin Orbit will deploy seven satellites, many of which were built with UK involvement

Countdown to the first ever space launch from UK soil could finally reach zero, with the first launch from Spaceport Cornwall expected to take place in November this year (exact date yet to be confirmed at the time of writing).

The mission, called 'Start Me Up', is being carried out by private spaceflight company Virgin Orbit and will also be the first private launch from anywhere in Europe. The launch will be in two stages, the first of which uses a modified Boeing 747 aircraft, called Cosmic Girl, to reach an altitude of around 10,000km. The plane arrived at Cornwall's Newquay Airport on 11 October.

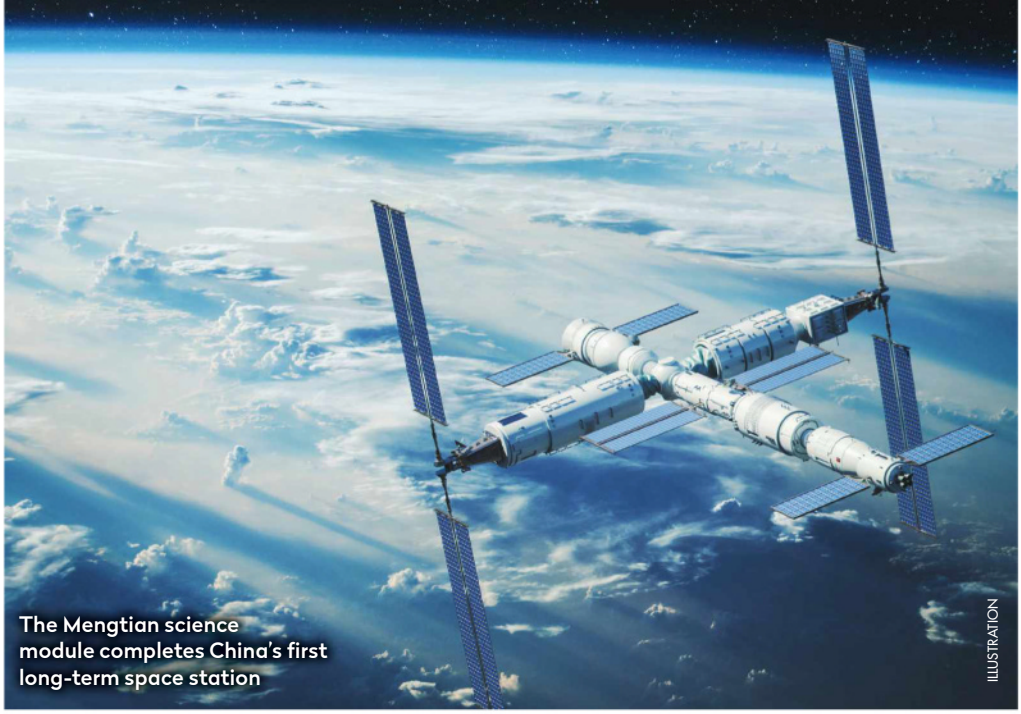
"Seeing Virgin Orbit's aircraft take off is an exciting reminder that we are close to the first launch from UK soil and the first launch of a satellite from Europe," says Ian Annett, Deputy CEO of the UK Space Agency.

Once at altitude, the carrier plane will drop a 21-metre LauncherOne rocket attached beneath its wing. After four seconds of freefall, the rocket will fire its engines to travel towards low-Earth orbit at 12,875km/h.

Once in orbit it will deploy its payload of seven small satellites, many of which were built at least in part by the UK space industry. These span a wide range of purposes, from monitoring the environment to preventing illegal trafficking and terrorism, as well as several technology demonstrations. It will also feature the first orbital mission from the Sultanate of Oman.

The launch is hoped to be the first of many from UK soil, taking place not just from Cornwall but from another spaceport currently under construction in Sutherland in the Highlands of Scotland. Unlike Cornwall, which can only host 'horizontal launches' that take off like a plane, Sutherland will be able to host traditional vertical rocket launches, making the UK an even more attractive place to launch satellites from. Both sites are part of the UK Space Agency's long-term plan to make the UK a major player in the spaceflight industry.

"What an incredible honour it is for us to be part of something as monumental as bringing Britain into the business of launch," says Dan Hart, CEO of Virgin Orbit. **www.virginorbit.com**



The Mengtian science module completes China's first long-term space station

ILLUSTRATION

Chinese Space Station completed

The finished Tiangong station can hold up to six people

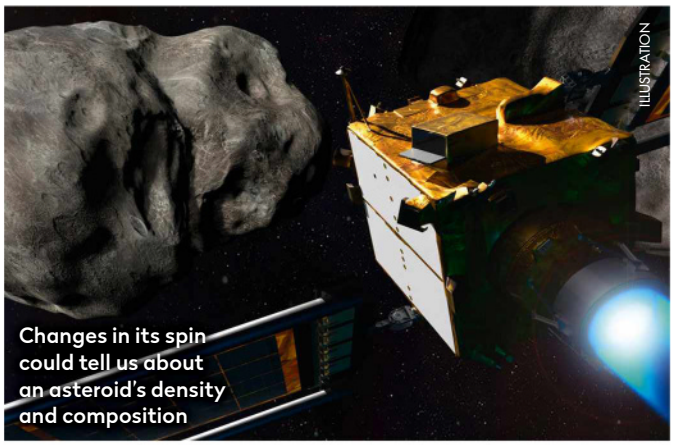
The Chinese Space Station, Tiangong, is now complete after the final science module, Mengtian, launched on 31 October at 07:37 UT. The station began construction with the Tianhe module in April 2021, followed by the Wentian module in July 2022.

Mengtian will serve as both a cabin module and a laboratory where taikonauts – Chinese astronauts – can perform experiments in zero gravity. One of the first is an ultra-cold experiment to cool atoms to one billionth of a degree below absolute zero, the lowest temperature ever achieved. Mengtian also has an airlock to help place experiments on the hull to expose them to the vacuum of space.

The semi-constructed station has already had several crews of three stay on board, but now the completed Tiangong can support up to six people. For comparison, the International Space Station, which has 16 modules, can host a maximum of 13 spacefarers.

www.cnsa.gov.cn

Asteroid behaviour reveals its inside story



Changes in its spin could tell us about an asteroid's density and composition

ILLUSTRATION

An undergraduate project by a student at MIT could help researchers map the interiors of asteroids that pose a collision risk with Earth. Physics major Jack Dinsmore simulated how the orbit and spin of an asteroid changes when it passes close to Earth and noticed it strongly depended on the shape and physical properties of the asteroid.

Developing the idea further, he realised the changes carried information about the asteroid's internal properties too. By measuring these small variations when an asteroid passes close to a large object, such as Earth, it may be possible to determine what the asteroid's internal structure is like. One important use of this could be in monitoring potentially hazardous asteroids, such as Apophis.

"Apophis will miss Earth in 2029 and scientists have cleared it for its next few encounters, but we can't clear it forever," says Dinsmore, now a graduate student at Stanford University. "It's good to understand the nature of this particular asteroid, because if we ever need to redirect it, it's important to understand what it's made of."

For more about asteroid-deflecting planetary defence plans, **turn to page 60**.

www.mit.edu

NEWS IN BRIEF

Possible November Artemis I launch

Will it be third time lucky for Artemis I? NASA has repaired the issues preventing the previous two launch attempts, as well as damage from Hurricane Ian. The rocket will return to the launch pad on 4 November, with a first launch attempt due on 14 November at 04:07 GMT.

A tight-knit pair

A 'cataclysmic variable' binary pair of stars has been discovered orbiting each other once every 51 minutes – the shortest timing known to date. The pair, located in Hercules, will get even closer together over the next 70 million years, eventually reaching an orbit time of just 18 minutes before drifting away from each other.

Red alert for supergiants

Red supergiants could blink out a warning alert before they go supernova, as dust building up around them causes their light to dim by up to 100 times, it's been discovered. Our nearest such star, Betelgeuse, exhibited slight dimming in 2019, but not enough to herald an imminent explosion.

NEWS IN BRIEF

Native American woman in space

Nicole Aunapu Mann, a member of the Wailacki of the Round Valley Indian Tribes in northern California, has become the first Native American woman in space. She launched to the International Space Station on board SpaceX's Crew Dragon on 5 October.

Wobbly black holes

A pair of colliding black holes, dubbed GW200129, are orbiting each other so quickly they're distorting spacetime, causing them to wobble about their axis (an effect known as precession) faster than any pair seen before. Discovered using gravitational waves, the duo precess every few seconds – 10 billion times faster than any previously measured.

Five years to deorbit

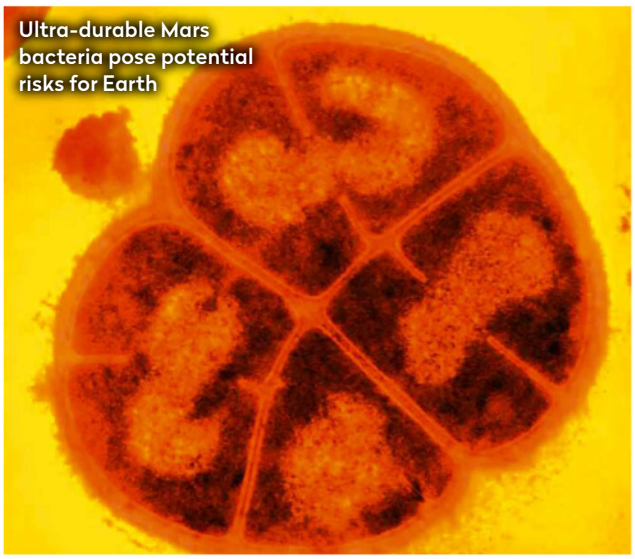
The US's Federal Communications Commission has changed its rules, reducing the time operators have to deorbit defunct spacecraft from 25 years to just five, in an effort to combat space debris. The new rule affects all satellites that launch from US soil and orbit under 2,000km.

NASA X 2, MICHAEL DALY/USU

BULLETIN

Ancient microbes may survive Mars radiation

The discovery could lead to tighter planetary protection



Ultra-durable Mars bacteria pose potential risks for Earth

Bacteria could survive Mars's radiation much longer than previously thought, a new study has found. Past experiments that subjected Deinococcus radiodurans – nicknamed Conan the Bacterium due to its hardiness – to the radiation it would experience just below the Martian surface found it could survive one million years. However, the new experiments froze and dried the bacteria, as would probably be the case on Mars, and buried it 10 metres down. Here it could withstand 280 million years of radiation.

Though the find raises hopes of finding life on Mars, it does mean preventing cross-contamination is even more critical.

"We concluded that terrestrial contamination of Mars would essentially be permanent – over timeframes of thousands of years," says Brian Hoffman from Northwestern University. "Likewise, if microbes evolved on Mars, they could be capable of surviving until the present day. That means returning Mars samples could contaminate Earth."

www.northwestern.edu

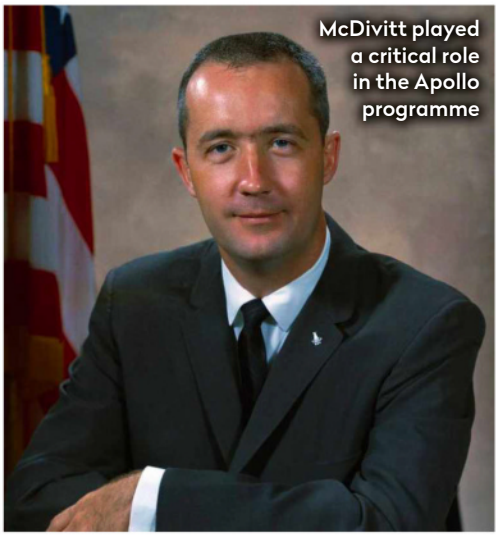
Apollo 9's James McDivitt dies, aged 93

Astronaut James McDivitt, who commanded both the Gemini IV and Apollo 9 space missions, died on 13 October.

Born on 10 June 1929 in Chicago, McDivitt joined the US Air Force at the age of 21. He flew over 5,000 flight hours on 145 combat missions during the Korean War and was later an experimental test pilot, eventually earning the rank of brigadier general.

McDivitt joined NASA in 1962 as part of the agency's second astronaut class. His first space mission, Gemini IV, was double the length of any previous NASA mission and included the first-ever US spacewalk, by his fellow astronaut Ed White. McDivitt's second flight, Apollo 9, was the first carried out with the Apollo lunar module. He and his crew performed several manoeuvres with the module in low-Earth orbit to qualify it for lunar flight, mimicking the trials it would go through in future landing missions.

He became the manager of the Apollo Spacecraft Program in August 1969, overseeing it from Apollo 12 to 16, eventually retiring in June 1972 and spending the rest of his career working in industry.



McDivitt played a critical role in the Apollo programme

www.nasa.gov

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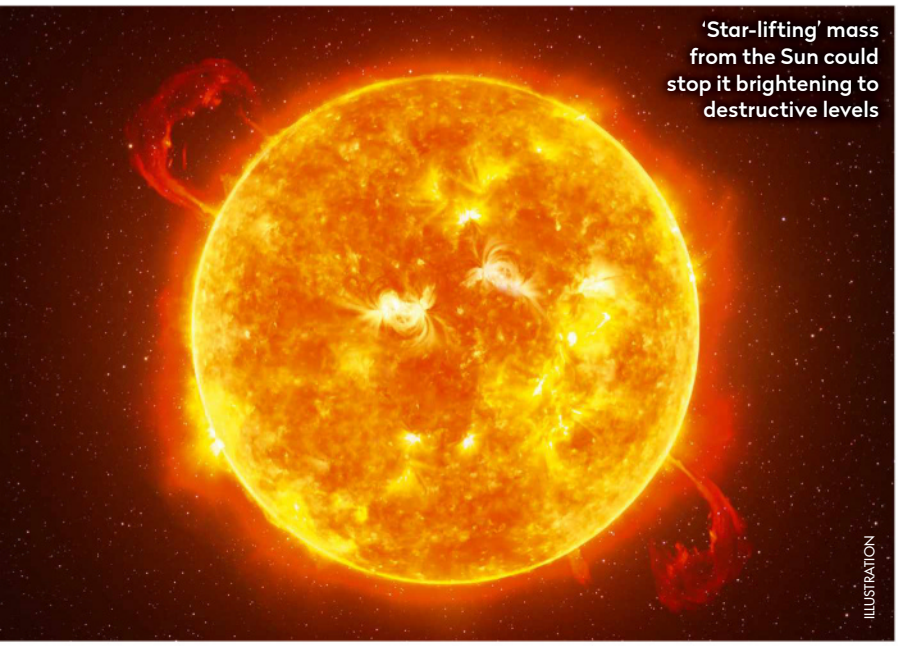


'Star-lifting' mass from the Sun could stop it brightening to destructive levels

ILLUSTRATION

Taking chunks from the Sun to save the world

Could reducing the Sun's mass save the far-future Earth from destruction?

There is a cosmic limitation facing life on Earth, as our Sun steadily brightens through its lifetime on the main sequence before ballooning into a red giant. This planet-sterilising red giant phase won't begin for another five billion years or so, so a natural question might be what could we do in the distant future to try to preserve the habitability of our world? Various high-concept proposals have been put forward, including a carefully orchestrated programme of flinging asteroids past Earth to boost the planet into a more distant orbit as the Sun brightens, exploiting the same physics as the gravitational slingshot method used to propel space probes.

Matthew Scoggins and David Kipping, both at Columbia University's department of astronomy in New York, have been investigating another ultra-long-term, high-tech possibility. One way for an advanced civilisation to counteract the brightening of their star as it ages is to progressively remove mass from it and so slow the rate of fusion reactions in its core. Scoggins and Kipping dub such artificially engineered suns 'Lazarus stars', after the biblical figure raised from the dead. Although they note that this method of 'star-lifting' was proposed by David Criswell back in 1985, here the authors have actually done the numerical calculations to work out exactly what would be needed.

Stellar smash and grab

They considered two slightly different scenarios. The first keeps the Sun at a constant brightness, or isoluminosity, by stripping mass from it and then storing it in orbit between Earth and the Sun. The second approach maintains the same amount of sunlight falling on Earth – isoirradiance – by removing less solar mass at first but then ejecting it out of the Solar System so that the orbit of the planet also drifts outwards with the reduced gravitational hold.

Scoggins and Kipping calculate that changing the planet's orbit with the isoirradiance approach can extend the Sun's lifetime on the main sequence – and thus the potential for life on Earth – by around six billion years. Doing so would require lifting a solar mass equivalent to two per cent that of the largest asteroid, Ceres, every year. The isoluminosity approach, which stores the removed mass, would require more to be stripped away at first, but could extend life on Earth by 10 billion years. Such a cosmic engineering project would require prodigious amounts of energy – the equivalent to 10 billion times the current annual energy consumption of our entire global civilisation. The isoirradiance method would need 100 times more than even that to eject the material from the Solar System. But as the researchers point out, the Sun is itself an enormous source of energy and an advanced civilisation would only need to capture 0.03 per cent of its annual output to power such an exercise.

> ***"Changing the planet's orbit can extend the Sun's lifetime – and thus the potential for life on Earth – by around six billion years"***

Although they don't attempt to speculate on what sort of advanced technology might enable this kind of stellar engineering, this study does offer an intriguing glimpse into what the far future of humanity may hold in store.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Lazarus Stars: Numerical Investigations of Stellar Evolution with Star-lifting* by Matthew Scoggins and David Kipping. **Read it online at: arxiv.org/abs/2210.02338**

DZIKA_MROWKA/ISTOCK/GETTY IMAGES, MARK GARLICK/SCIENCE PHOTO LIBRARY/ALAMY STOCK PHOTO

When a star meets a black hole

A growing black hole needs to eat, and makes a mess when it does

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

Everyone loves black holes, especially when they're doing classic black hole things like ripping stars apart and consuming them whole. The authors of this month's paper, led by Fulya Kiroglu from Northwestern University just outside Chicago, use powerful simulations to look at what happens when a Sun-like star, minding its own business, encounters a black hole which outweighs it by a factor of between a hundred and a thousand.

I should say at the start that it's not very clear that black holes of this intermediate size actually exist. We know smaller ones do, formed in supernovae at the end of a massive star's lifetime, and gravitational wave experiments have detected mergers of black holes that add up to about 100 solar masses. We also know that supermassive examples, weighing millions of times the mass of the Sun, live at the centres of galaxies. But in between – maybe – are black holes that form from the deaths of the most massive stars, or via merging with other black holes in the middle of dense star clusters. In either case, one way of detecting these elusive beasts would be to spot them as they grow by swallowing their stellar companions whole. Consuming a star should make a mess and it has been suggested that bright sources of X-rays found in the right sorts of star clusters might be caused in just this way, but that means we need better simulated models of what, exactly, happens when a star comes close to the black hole.

Taken captive

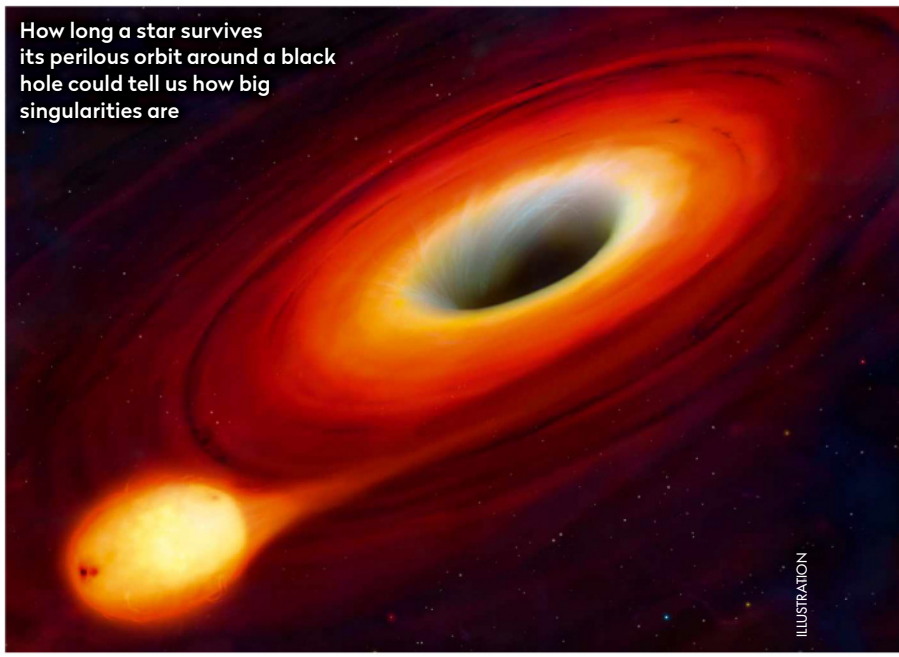
The answer, the team find, is that 'it varies'. If the star keeps its distance, then it might get away with little lasting change. If it gets too close, though, it will be ripped apart. The simulations show that even a first passage close to the black hole, prior to being captured into orbit, will see the star lose a lot of mass. The disrupted star may even be ejected from the system after this initial encounter, or captured into an orbit where the black hole will cannibalise ever more of the star's mass on each subsequent passage.

"This is exciting. If we can detect X-ray flares, we should be able to work out how massive the black hole is from counting the flashes"

This seems to happen again and again. In one example looked at by the researchers, a star encountering a 10-solar-mass black hole swings by 16 times before what's left of it is ejected back into the cluster. For larger black holes, the number of orbits a star can survive is smaller, with a star orbiting around a 100-solar-mass black hole withstanding just five passages.

This is exciting; it means that if we can detect X-ray flares from the material being ripped from the stars, then we should see a repeating pattern of such events marking the position of a black hole and be able to work out how massive it is from counting the number of flashes.

The simulations also show that each flare should be brighter than the last, creating a distinct signature that could be used to recognise these systems. Of course, more work – by which I mean creating more simulations, including stars of different sizes, masses and ages, as well as more details of the processes in play – is necessary, but in a year or two we could be hearing news that we've finally filled in the missing link of black hole evolution, thanks to the flashing X-rays produced as examples consume stars.



How long a star survives its perilous orbit around a black hole could tell us how big singularities are

ILLUSTRATION

Chris Lintott was reading... *Tidal Disruption of Main-sequence Stars by Intermediate-mass Black Holes* by Fulya Kiroglu et al.
Read it online at: arxiv.org/abs/2210.08002

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT

ILLUSTRATION

SKAO, STOCKTREK IMAGES, INC./ALAMY STOCK PHOTO, BBC

As November's *Sky at Night* looks at the Universe's mysteries, **Emma Chapman** tells us how radio astronomy got her hooked on solving them

▲ **Tuned to the Universe: an artist's impression of the Square Kilometre Array, which Emma works with. Currently under construction in Australia (right) and South Africa (left), it will be the largest, most sensitive radio telescope on Earth**

Few people dream of being a radio astronomer. Many of the origin stories of my colleagues involve frosty nights learning the constellations or else convey the sublime nature of seeing the rings of Saturn for the first time. It's less common to hear of a childhood calibrating an antenna to listen to the pings of meteors or the hiss of solar flares. Indeed, I cannot offer that story either. I grew up wanting to be an Egyptologist who spent her days brushing away sand from hidden treasures and decoding ancient messages.

Having read every archeological book in the library, my teenaged eyes had wandered to the popular science shelf. Until then, I had enjoyed physics, but I didn't know that the subject still held any real mystery and wonder. I had so many new questions that, rather last minute, I changed my career path. It was the history of the Universe that fascinated me most of all, especially when I learned we could observe the light from the early Universe. I had found the ultimate archeological ruins.

When I was assigned a PhD project to search for the first stars using radio telescopes, I had mixed feelings. I had never heard of anybody searching for the first stars and I was excited to hear of the unexplored first billion years in our timeline. The primordial Universe contained only hydrogen and helium, and without the cooling effects of heavier elements the first stars formed on the order of one hundred solar masses. The collapsing force of such a mass of gas meant that fusion progressed quickly. Within only tens of millions of years, this generation of stars became extinct in brilliantly energetic supernovae, seeding their environment with the heavier elemental products of fusion. The first stars are an extinct species: they cannot form in the polluted space of today. But they left their messages in the light that is only just reaching us now.

Sleuthing for signals

The first stars and baby black holes were mine for the uncovering, but I needed a tool not usually in an archeologist's (or most astronomers') tool belt:

Emma Chapman is a Royal Society research fellow based at the University of Nottingham and author of *First Light*

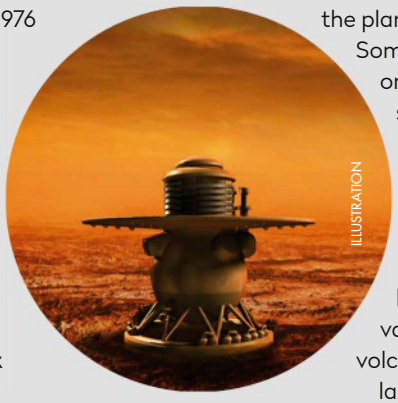
a radio antenna. Not quite the clean rooms and rocket launches of NASA, or the clear nights observing up mountains in Hawaii that I had envisaged, but the mystery was too great for me not to pursue. Optical astronomy is, of course, far more intuitive to us. We have two little telescopes sitting in our head through which we view the world, but only in optical wavelengths. Light is a spectrum, comprising a huge range of wavelengths, of which the optical spectrum occupies only a tiny sliver. Radio light can help us look at the Universe differently. By placing 131,000 deceptively simple Christmas tree-like metal antennas in the Western Australian desert (as well as an additional 200 dishes in South Africa) to build a radio telescope called the Square Kilometre Array, we are planning to stream the home movie of this missing era, picking up signals from the furthest reaches of space to finally uncover the stars that started it all.

When I was a teenager, I dreamt of walking through the sands of Egypt. And now, yes my boots are dusty with sand, but it is from visiting the remote radio observatories that have given us a window back to the very beginning. I am no longer searching for what might be hidden under my feet. Instead, I am looking up: a historian armed with a telescope.

Looking back: The Sky at Night

15 December 1976

When the December 1976 episode of *The Sky at Night* was broadcast, Venus was shining brilliantly in the evening sky. Our understanding of the cloud-covered planet had changed dramatically by the middle of the 20th century and so Patrick Moore took this episode as an opportunity to have a closer look at Venus.



▲ **Venera 14 touched down on Venus in March 1984 and managed to last 57 minutes**

In 1956, radio measurements of the Venusian atmosphere suggested the planet's temperature could be several hundred degrees higher than previously thought – and indeed the surface was later found to be 475°C, with a pressure a crushing 92 times that of Earth.

The first real examination of the planet came from the Soviet Venera programme, 16 missions that explored the planet from 1961 to 1984. Some of these were orbital, their fly-by spacecraft using radar to pierce the clouds and map out the planet's surface. These revealed a craggy and cratered landscape, covered in valleys, mountains and volcanoes. But it was the landing missions that really gave us a close-up view of Venus. The thick atmosphere meant it was possible to float to the surface on a parachute – the tricky part was building a craft that could survive the hellish atmosphere long enough to make it. However, several of the Venera missions managed the journey and in October 1975 Venera 9 sent back the first-ever pictures from the planet's surface, revealing the boulder-strewn landscape, dimly-lit beneath the clouds.

The Sky at Night

First Contact: An Alien Encounter

There's no episode of *The Sky at Night* in December, but instead you can catch up with this '21st-century *War of the Worlds*', which is available to watch on the BBC iPlayer. *First Contact* is a feature-length drama documentary imagining what might happen if humanity detected evidence of an extraterrestrial civilisation. Based on interviews with SETI expert Jill Tarter, the drama attempts to answer one of the greatest questions facing humanity: what happens if we find out we are not alone?

www.bbc.co.uk/programmes/m001ctnr

▲ **How would humanity react if we discovered extraterrestrial intelligence?**

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

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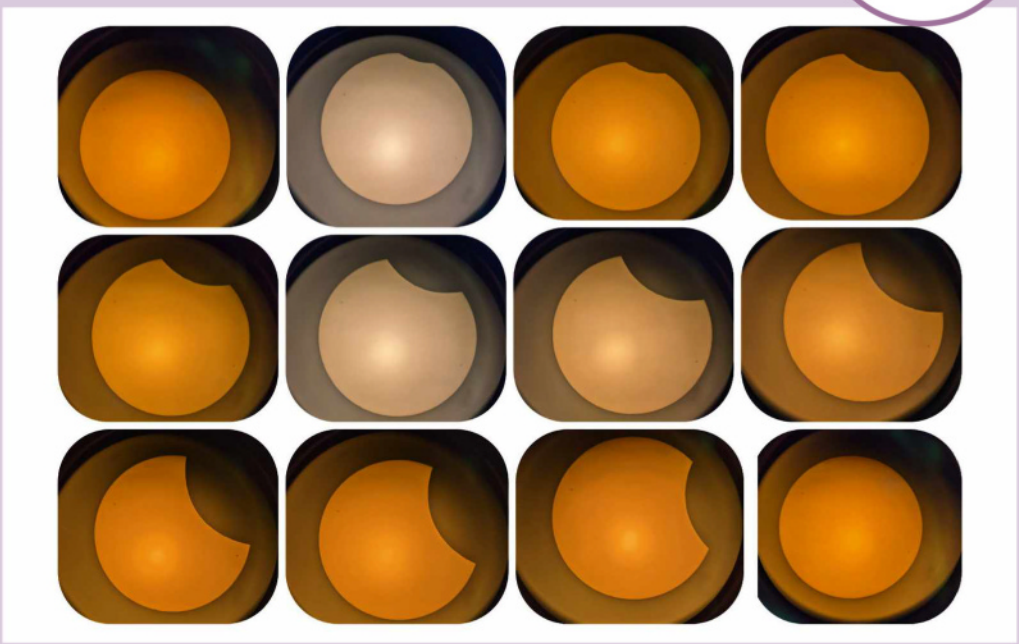
MESSAGE OF THE MONTH

This month's top prize: two Philip's titles

The 'Message of the Month' writer will receive a bundle of two top titles courtesy of astronomy publisher Philip's: Nigel Henbest's *Stargazing 2023* and Robin Scagell's *Guide to the Northern Constellations*

Winner's details will be passed on to Octopus Publishing to fulfil the prize



▲ **Debbie's eclipse montage created with the help of a collage app on her smartphone**

Solar showcase

I captured the images above today during the partial solar eclipse using my Google Pixel 4 smartphone and Celestron NexStar 8SE telescope with solar filter attached!
Debbie Townsend, Doncaster

What a great record of the event, Debbie! Your montage of the whole passage of the eclipse is a really effective way to present the afocal images you captured on the day. ***– Ed.***

Nifty shades of Graham: geared up for the eclipse

The glare essentials

For the partial solar eclipse on 25 October, I used a 4-inch reflecting telescope to project the Sun's image onto a screen in my garden, capturing it with my mobile phone. I also viewed the eclipse with a pair of solar eclipse glasses that I have owned since 1999, when I bought them for the total solar eclipse.
Graham Sinagola, via email

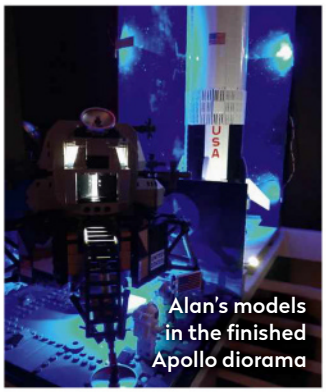
Model behaviour

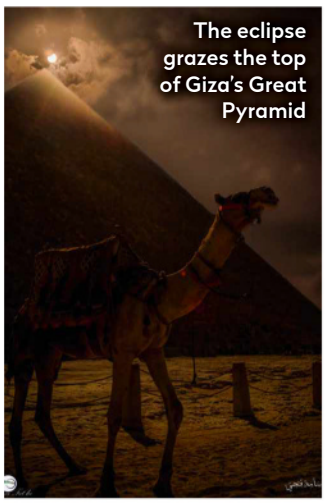
Having read in the November issue's Message of the Month about the young lad who had made the Lego model of the Apollo 11 lunar module, I can endorse just how pleased he would have been to have put this terrific model together. Last Christmas my daughter bought me the very same kit and I was equally pleased at the result, so much so that I treated myself to the Saturn V Apollo rocket model. This was equally as impressive once constructed, standing around a metre high! Having created a diorama to display the model of the lunar module, I then set about creating one for the Saturn V. I'm old enough to have witnessed the Apollo 11 Moon landing in 1969 and I'm eagerly looking forward to witnessing the

Tweet

Alan crossland
@alan65834785 • 27 Sep
Winter skies are here! Andromeda rising over Beacon Mill, Rottingdean. #Andromeda #astrophotography #Brighton #stars #Southdowns

next, although I didn't expect to have waited so long!
Alan J Robinson, Cheshunt


Alan's models in the finished Apollo diorama


The eclipse grazes the top of Giza's Great Pyramid

Giza teaser

This photo (above) was taken a few minutes after the peak of the partial solar eclipse from the Great Pyramid of Giza. The duration of the eclipse in Cairo was two hours, but the weather conditions were so extreme there were only 30 minutes without heavy cloud cover. I had been planning this image for three months and made three visits to the Great Pyramid to select the best scene. I also bought a Sigma 28–70mm lens and Formatt-Hitech ND 3.0 nautral density filter for my modified Nikon Z6 camera especially for this capture.
Osama Fathi, Cairo ▸

ON FACEBOOK

WE ASKED: Why do we always see the same side of the Moon?

Steve Green Is this a trick question? The moon is a sphere, so it doesn't have a side!

Ed Jonze I thought it was in synchronous rotation with Earth but no – it's apparently some white-tac that got stuck on the camera lens.

Gilles Blanchette The Moon rotates one turn in the same number of days that it takes to make one revolution around the Earth. That's why we always see the same side of the Moon.

Philip Horn-Botha Coz the Moon is shy? The other side is full of junk?

Pete Madge The Moon's rotational period is almost the same as its orbital period around its parent body, with some libration.

Mark Pearsons The 19 largest moons in our Solar System are all tidally locked to their host planets.

Stephen Croft Because a lunar day is about 29.5 Earth days.

SCOPE DOCTOR

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I have a pair of Celestron SkyMaster 20x80 binoculars with a Horizon Heavy Duty Tripod, but I find the screw in the tripod's mounting plate is too short to hold the binoculars. Am I doing something wrong?

ROGER ROOKES


STEVE RICHARDS
▲ A male to female adaptor should solve the problem

This is a rather puzzling problem as there is no reason why this combination shouldn't work correctly. The binoculars have an adjustable, but not removable, tripod adaptor attached to a cylindrical bar running from the front to the back. This adaptor is tightened onto the bar using a thumb bolt at the top and projects downwards, exiting from underneath the binoculars where you will find a 1/4–20 threaded hole. The captive bolt in the Horizon Heavy Duty Tripod's quick-release mounting plate screws into this threaded hole. The quick-release plate is then fitted into the quick-release shoe at the top of the tripod and locked in place.

If the plate cannot be attached to the binoculars' tripod adaptor for some reason, a simple solution would be to use a small 1/4-inch male to 1/4-inch female tripod adaptor between the binoculars' adaptor and the mount's quick-release plate.

Steve's top tip

How can I prevent vignetting?

Vignetting is the appearance of the light intensity through a telescope falling off towards the edges of the field of view, and can be very obvious in deep-sky images. It can be caused by an obstruction in the light path, the natural effect of light passing through a lens, or pixel vignetting where light falling on the edges of a sensor arrives at a slight angle, whereas light falling on the centre arrives perpendicular.

The cure for all forms of vignetting is to calibrate your images with a series of 'flat' frames, captured with a diffuse material over the front of the telescope while aimed at an even light source, such as a cloudy daytime sky.

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

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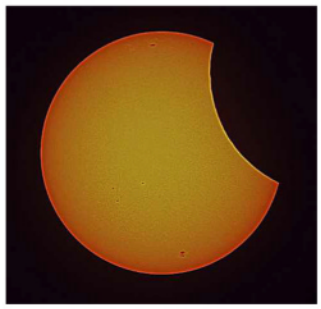
IPAC/CALTECH BY THOMAS JARRE

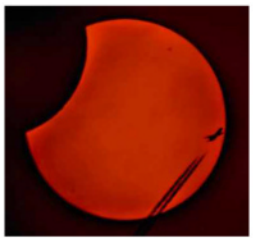
Instagram

cellistontheroof • 25 October

My only option for getting an image today was the RedCat51 with an Explore Scientific white-light solar filter and ZWO ASI224MC – the only setup that can fit the whole Sun in frame. I couldn't get my larger telescope out because while the Sun was out it was actually RAINING! #solareclipse #astrophotography



In plane sight



This is my first shot with the Sun and a plane. I was trying to focus the Sun to take a photo when a plane went by, so I just clicked quickly, which explains why it's not in the best focus. But I'm over the Moon that my first shot of the Sun with a plane also included the partial solar eclipse! The equipment I used was a Sky-Watcher 10-inch Dobsonian, Seymour thin solar film and a Google Pixel 6 smartphone.
Sonia Turkington, North Reddish, Stockport

Norman caught a brief break in the clouds

Cloud pleaser

For me, the 25 October eclipse was hampered by clouds almost throughout the event, however I managed to get a few pictures I was happy with. I took this image with a hand-held Canon R6 camera and RF70–200mm lens at 200mm, using a Lee Big Stopper 10x neutral density filter.
Norman Woolley, via email

CORRECTION

In the feature 'Mars season has arrived' in our October 2022 issue, the caption for the map of Mars's surface features on page 62 mistakenly mentioned areocentric longitude, where it should simply have mentioned longitude.

SOCIETY IN FOCUS

Bristol Astronomical Society celebrates its 80th anniversary on 8 December. The UK was in the midst of the Second World War 80 years ago, with heavy bombing and air raids a common occurrence. But with the city lights out, the wonders of the night sky became more visible. In winter 1942 an advert in the *Bristol Evening Post* invited those with an interest in astronomy to join a meeting on 8 December.

Little is known about the group in the early years, but enthusiasm clearly grew. In the 1970s the society built an observatory southwest of the city in Failand. An 18-inch telescope was donated by Cyril Swindin CBE and the observatory was officially opened by Sir Patrick Moore in 1972.

The society is much changed. Our telescope is now a 12-inch Meade LX600, polar-aligned and fitted with a CCD camera, ideal for astrophotography, group viewings and Zoom meetings. We host star parties during autumn and winter and have a full calendar heading towards 2023.

▲ Bristol AS chair Fiona Lambert solar observing during an outreach event

Our meetings are held at the Bristol Photographic Society in the Montpelier area of the city. During the pandemic, they moved online to keep the society together during difficult times. Now, all meetings are over Zoom as well as at the BPS. For more info on our talks and observing events, visit our Facebook page or our website.
Fiona Lambert, Chair, Bristol Astronomical Society
▸ bristolastrosoc.org.uk

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON

MARY MCINTYRE, NATIONAL MARITIME MUSEUM X 4

A History of Women in Astronomy

University of Wolverhampton, 5 December, 7:30pm

Join Mary McIntyre FRAS and the Wolverhampton Astronomical Society for a talk celebrating the myriad contributions made by women to the science of astronomy.

www.wolvas.org.uk/event

The Goodwill Moon Rock

National Space Centre, Leicester, 7 December, 6:15pm and 8:15pm

A talk by Dermot Gethings, who as a student ambassador in 1972 was sent to cover the launch of Apollo 17 and became the custodian of the Apollo 17 Goodwill Moon Rock. Tickets £8.

spacecentre.co.uk/whats-on

Stargazing with Astro Dog

Dalby Forest, North Yorkshire, 8–23 December, 6:30pm

A laser-guided tour of the night sky in the North York Moors Dark Sky Reserve, with binoculars and telescopes available for viewing star clusters and nebulae. £20.

astro-dog.co.uk/collections/stargazing-events

Apollo 17's 50th anniversary

World Museum, Liverpool, 10 December

An exhibition by Liverpool Astronomical Society celebrating the 50th anniversary of humanity's last trip to the Moon, aboard Apollo 17. Expect talks, displays and even solar observing. Free to enter.

liverpoolas.org/events

PICK OF THE MONTH

▲ The after-hours festive talk discusses the latest scientific revelations from Mars

Annual Royal Observatory Christmas Lecture

Royal Observatory, Greenwich, London, 9 December, 7pm

This year's Christmas lecture at the Royal Observatory Greenwich comes from Professor Sanjeev Gupta of Imperial College, London, who will be speaking about Mars and the rover missions currently exploring it. The professor is well-placed to discuss this subject, being a planetary scientist researching environmental change on both the Red Planet and our own blue and green one, and also a co-investigator on the camera teams for the ExoMars, Curiosity and Perseverance Mars rovers. Booking essential. Tickets £10 for adults, £5 for children and £9 for students.

www.rmg.co.uk/whats-on

Comets and Meteoroids

Walthamstow Wetlands, London, 13 December, 6:30pm

A talk from Stow Stargazers on the differences between meteors, comets and asteroids, followed by a tour through the wetlands and a look for Geminid meteors, weather permitting. £20 entry.

www.wildlondon.org.uk/events

Christmas Astronomy Talk

Royal Observatory, Edinburgh, 19 December, 7pm

This family-friendly talk will cover the winter sky, 2022's space news and some Christmas surprises along the way. Tickets £7.50, £5 concessions.

visit.roe.ac.uk

Christmas Dark Skies Walk

Keswick, Cumbria, 23 December, 5:30pm

A walk of three to four miles around Whinlatter Forest Park with an astronomer guide to discover the night sky above the Lake District. Santa hats welcome. Tickets £10 adult and £15 for one adult with two kids under 12.

www.keswick.org/whats-on

mpb.com

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FIELD OF VIEW

In the bleak midwinter

Benjamin Skuse on the June celebration keeping South Pole astronomers sane

IceCube's 2022 winterovers at the geographic South Pole, where they combined Midwinter Day celebrations with a Pride parade

Benjamin Skuse is a freelance science writer who enjoys observing the night sky free of light pollution from the Somerset Levels

Here in the Northern Hemisphere, Christmas festivities and other celebrations help many of us to get through the bleak midwinter, when all is darkness and gloom, bitter cold and frosty wind.

But at the South Pole the festive period falls in the Antarctic summer, during the short work and tourist season. Down there it's not until after New Year that the days begin to rapidly shorten, when all the fair-weather Antarcticans wave goodbye to the continent for warmer climes. What's left are a thousand or so people that form skeleton crews for Antarctica's 70 permanent research stations. These hardy souls are known as 'winterovers'. Largely confined to their stations due to the extreme cold, biting wind and permanent darkness outside, winterovers can experience isolation and claustrophobia, infighting with crewmates, and can even have trouble perceiving the passage of time.

To combat these challenges and boost morale, in 1902 the British explorer Captain Robert Falcon Scott and his men planned a faux Christmas celebration on 21 June, which they called Midwinter Day. The day has since been embraced as a unique holiday, replete with its own traditions and events. Some stations plan a week of activities, others make gifts on an Antarctic theme from materials found on base, and all stations have a slap-up meal and send each other digital Midwinter greeting cards.

"The isolation does get to everyone after a while on one level or another, so it's good to have something to look forward to," says John Hardin, who spent two Christmases at the South Pole and winterovered for the IceCube Neutrino Observatory at the Amundsen–Scott South Pole Station in 2019/20. "It's a quieter thing, but Midwinter feels a little more meaningful to everybody – it's the holiday of Antarctica."

Winterover veterans Moreno Baricevic and Wenceslas Marie-Sainte were in charge of maintaining the unique IceCube Observatory this year, which is actually an experiment consisting of 5,160 detectors buried in a cubic kilometre of ice. Designed to pick up traces of rare neutrino interactions with matter, it helps scientists understand the cosmic origins of these nearly massless fundamental particles.

"We maintain IceCube's sensors, the huge amount of cables coming from them, and the IceCube Laboratory, where we have more than 100 computers that collect, process, filter and then send all the meaningful data up north in real time," says Baricevic on a videocall, sitting alongside Marie-Sainte, near the end of their 11-month stint at the Pole.

Working 24/7 and facing the same deprivations that Captain Scott and his men faced 120 years before, for the two researchers Midwinter is always a welcome pause. "We celebrate the fact that we as a community are passing those difficult days together," says Marie-Sainte, before Baricevic adds: "It's something that is very sacred."

The duo will be back in Italy and France by now, enjoying everything they had missed while away – which for Marie-Sainte includes riding his bike in the rain and having "a really good Belgian beer". But when 21 June rolls around, they will celebrate Midwinter again, a moment of pause and reflection upon their life-changing experience on the untouched continent.

AMAN CHOKSHI/SPT AND NSF

BBC

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BBC Sky at Night MAGAZINE

25 SIGHTS OF CHRISTMAS

Take a break from the festive hurly-burly, as Stuart Atkinson brings you a cosmic countdown to the big day with 25 celestial treats to find in the night sky this December

The Andromeda Galaxy sparkles at number 11 in our astronomical advent calendar

CHART BY PETE LAWRENCE. IMAGE BY MARCO LORENZI, WWW.GLITTERINGLIGHTS.COM/GETTY, SEBASTIAN VOLTMER/CCDGUIDE.COM, CLAUDIODIVIZIA/ISTOCK/GETTY IMAGES, BACKGROUND: GETTY

As the countdown to Christmas begins, we bring you glad tidings: if you have 'buy advent calendar!' on your shopping list, you can scribble it out, because this year we've produced a special astronomical advent calendar just for sky-watchers. There are no little cardboard doors to prise open and no strange-tasting chocolate snowmen to eat. Our calendar is the winter night sky and we're giving you 25 different, glorious sights to find in the run-up to Christmas.

So cross your fingers for good weather, because after you've dumped your shopping bags, and grabbed a cuppa and a mince pie, you can wrap up warm and head outside to enjoy a winter wonderland of bright planets, beautiful constellations and sparkling star clusters.

Many of our targets are visible with the naked eye, while some require binoculars or a small telescope. Stay clear of light pollution if you can and allow 30 minutes for your eyes to adapt to the dark. Use a red torch to find your way and turn your smartphone screen red if you want to consult an astronomy app, as this will help preserve your night vision.

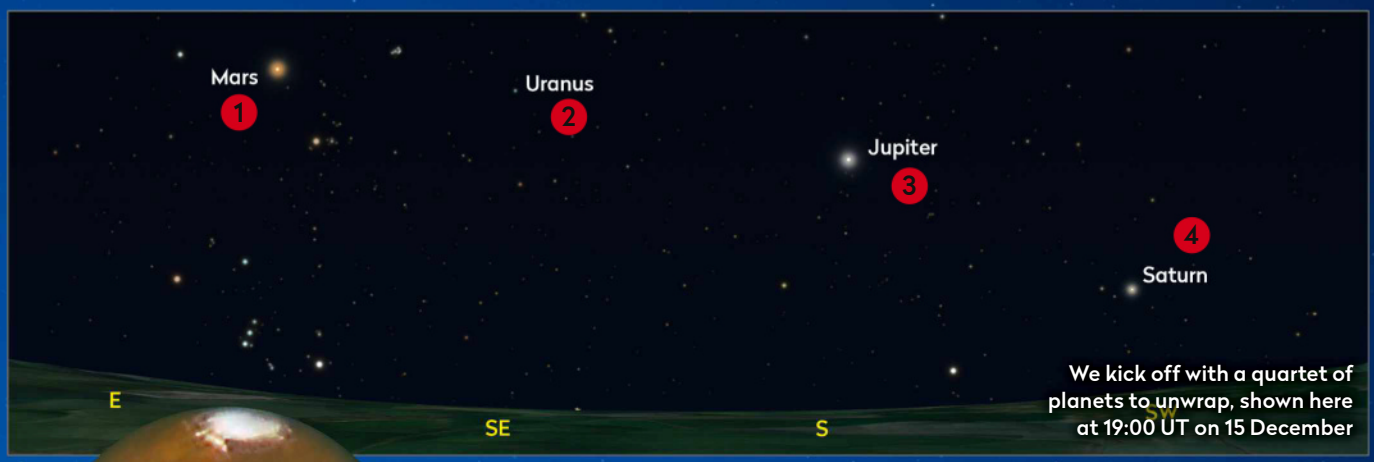
Each target is visible throughout December, so if one night is cloudy, just pick the next clear night and find a few of them. Our final target, however, is something of a Christmas present.

On Christmas Day afternoon, head outside in your Christmas jumper and catch a lovely gathering of the Moon and two planets in the twilight. Merry Christmas everyone. Let's get started!

Stuart Atkinson is a lifelong amateur astronomer and author of 11 books on astronomy

What kit to use

Naked eye | Binoculars | Small telescope | Large telescope



We kick off with a quartet of planets to unwrap, shown here at 19:00 UT on 15 December

1 Mars

The December sky belongs to Mars! Although known as the Red Planet, Mars is more of an orange colour in the sky, and this month it's a bright, marmalade 'star' blazing in Taurus, close to the Hyades and Pleiades star clusters. During early December, it reaches mag. –1.9, making it brighter than anything else around it, and the planet reaches opposition on the 8th. Even a small telescope will reveal the southern polar ice cap and dark markings on its surface. ☐ **SEEN IT**

2 Uranus

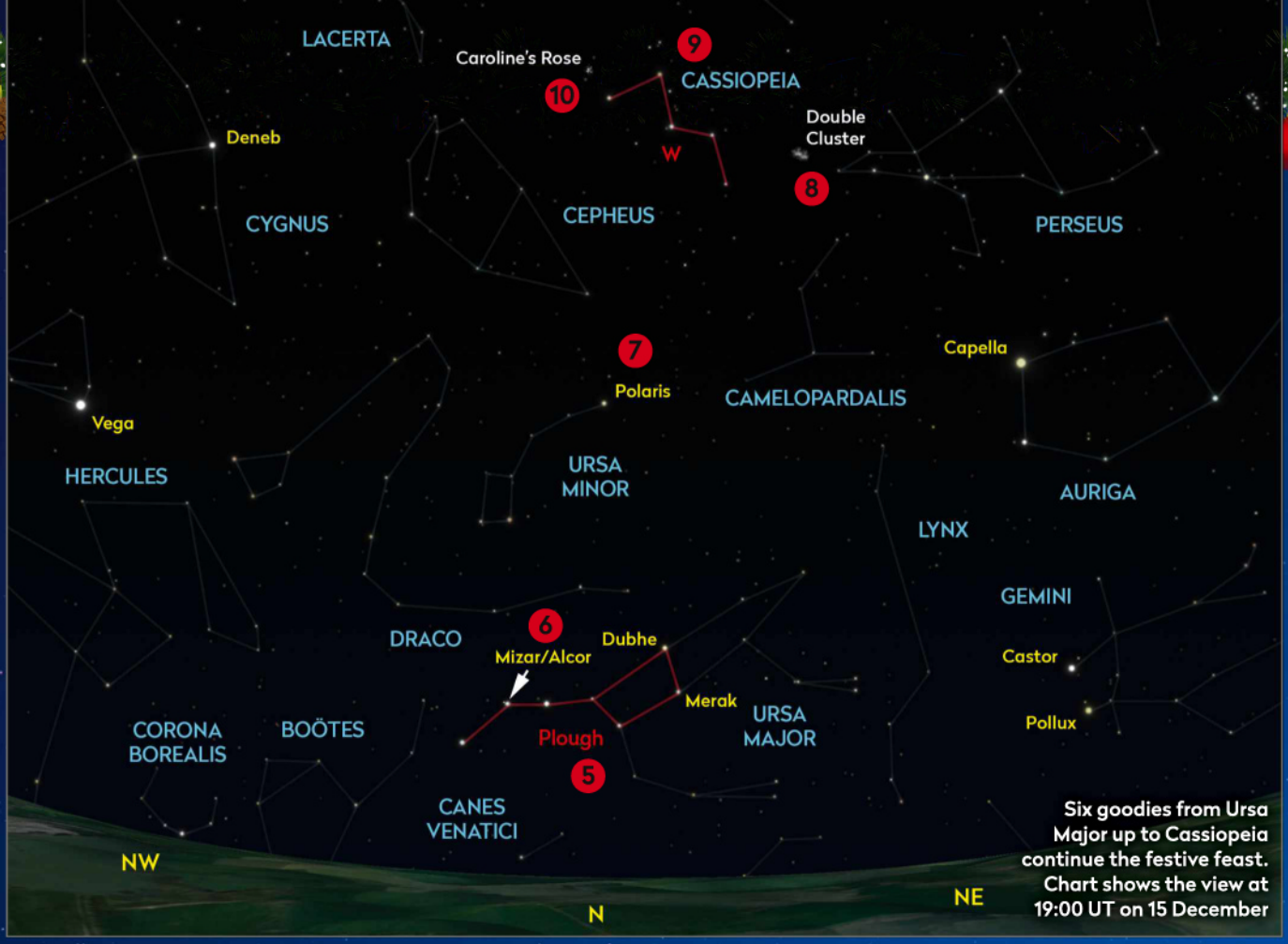
Shining at mag. +5.7, Uranus is technically visible to the naked eye, but unless you know the sky very well and can tell exactly which of the many faint lights in Aries is the ice giant planet, you'll need binoculars to pick it out. If you spot a green-hued 'star' 15.5° to the west of the Pleiades star cluster after dark, you've found Uranus! ☐ **SEEN IT**

3 Jupiter

Half an hour after sunset on December evenings, look to the southeast and you'll see a bright blue-white 'star' shining above the skyline, obvious to the naked eye at mag. –2.4. This is Jupiter, the largest planet in our Solar System. With binoculars you'll be able to see up to four of its family of 80+ moons, and a telescope will show horizontal bands of toffee- and coffee-hued cloud on its slightly flattened creamy disc. ☐ **SEEN IT** ▸

4 Saturn

Having found Jupiter shining in the southeast, look to its south and slightly lower in the sky to see another planet: Saturn. At mag. –0.8, the ringed giant is fainter than Jupiter and more of a yellow-white hue. You'll need a telescope to see its famous rings, but binoculars will reveal its largest moon, planet-sized Titan, shining close by. ☐ **SEEN IT**

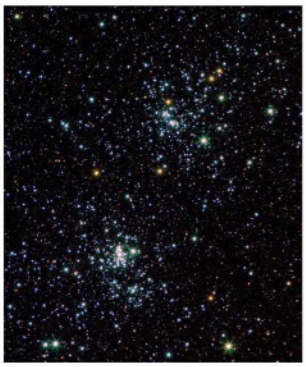


Six goodies from Ursa Major up to Cassiopeia continue the festive feast. Chart shows the view at 19:00 UT on 15 December

5 The Plough (aka The Big Dipper)

One of the most famous night-sky sights of all, The Plough isn't actually a constellation but an asterism, a small pattern of stars obvious to the naked eye. The Plough is part of the constellation Ursa Major. As darkness falls on December evenings, it looks a lot like a question mark of stars low in the north. ☐ **SEEN IT**

8 Double Cluster



Located roughly halfway between the 'W' of Cassiopeia and the inverted 'Y' of Perseus, this pair of star clusters, so close together they are almost touching, is a favourite of many amateur astronomers. Visible as a smudge to the naked eye, binoculars and small telescopes reveal two clusters of pinprick stars, looking like piles of salt spilled on a black tabletop. ☐ **SEEN IT**

6 Mizar/Alcor

This double star can be found in the centre of the Plough's handle. You may be able to split the pair with your naked eye, but if not then a pair of binoculars or a small telescope will give you very crisp views. Mizar, the brighter of the two, shines at second magnitude, while fainter Alcor has a brightness of mag. +4. ☐ **SEEN IT**

9 Cassiopeia

This small constellation is an unmistakeable highlight of the northern sky. If you face south after dark and tilt your head right back, almost directly overhead you'll see a 'W' of silvery-white stars all of roughly the same brightness. Because Cassiopeia is embedded in the Milky Way, if you sweep your binoculars around it you will see countless thousands of fainter stars. ☐ **SEEN IT**

7 Polaris

Many think that Polaris, aka The Pole Star, is the brightest star in the sky, but at mag. +1.97, it is only the 48th brightest. However, it is perhaps the most important star in the northern sky because it is almost directly above Earth's north polar axis, and as our planet spins all the stars appear to wheel around it while it seems to remain stationary. ☐ **SEEN IT**

10 Caroline's Rose

Caroline's Rose is an open cluster in Cassiopeia named in honour of astronomer Caroline Herschel, sister of William. Around 8,000 lightyears away, its flowery name comes from its loops and curls of orange and blue stars that form the shape of rose petals when viewed through a telescope. ☐ **SEEN IT**

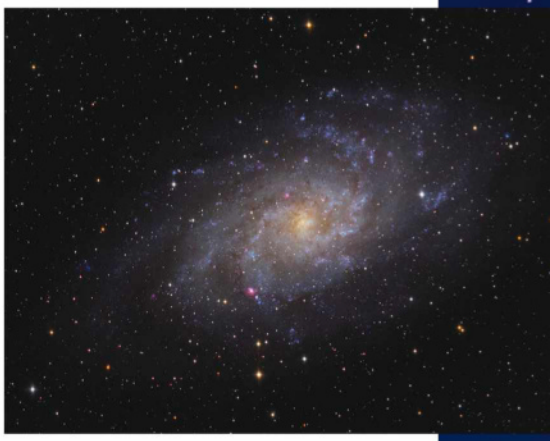
CHARTS BY PETE LAWRENCE, ROBERT SCHULZ/CCDGUIDE.COM, GÜNTER KERSCHHUBER/CCDGUIDE.COM, CHRISTOPH KALTSEIS/CCDGUIDE.COM, JOHANNES SCHEDLER/CCDGUIDE.COM, BACKGROUND: GETTY

11 M31

To the naked eye M31, the Andromeda Galaxy, is an elongated smudge below Cassiopeia, but through binoculars or a small telescope you will see it is a beautiful, lens-shaped patch of misty light much larger than the full Moon, with a noticeably brighter centre. A giant spiral galaxy, bigger than our own Milky Way, it is 2.2 million lightyears away – the most distant object visible to the naked eye. ☐ **SEEN IT**

12 M33

Although not as large in the sky as its near neighbour M31, and a lot fainter too (mag. +5.8 vs mag. +3), M33, the Triangulum Galaxy, can just about be seen with the naked eye on nights of good seeing under skies free of light pollution. Through binoculars and telescopes this face-on spiral galaxy looks like a small, round smear. Larger telescopes and long-exposure photos reveal its beautifully curved spiral arms, mottled with star clouds. ☐ **SEEN IT**



13 M15

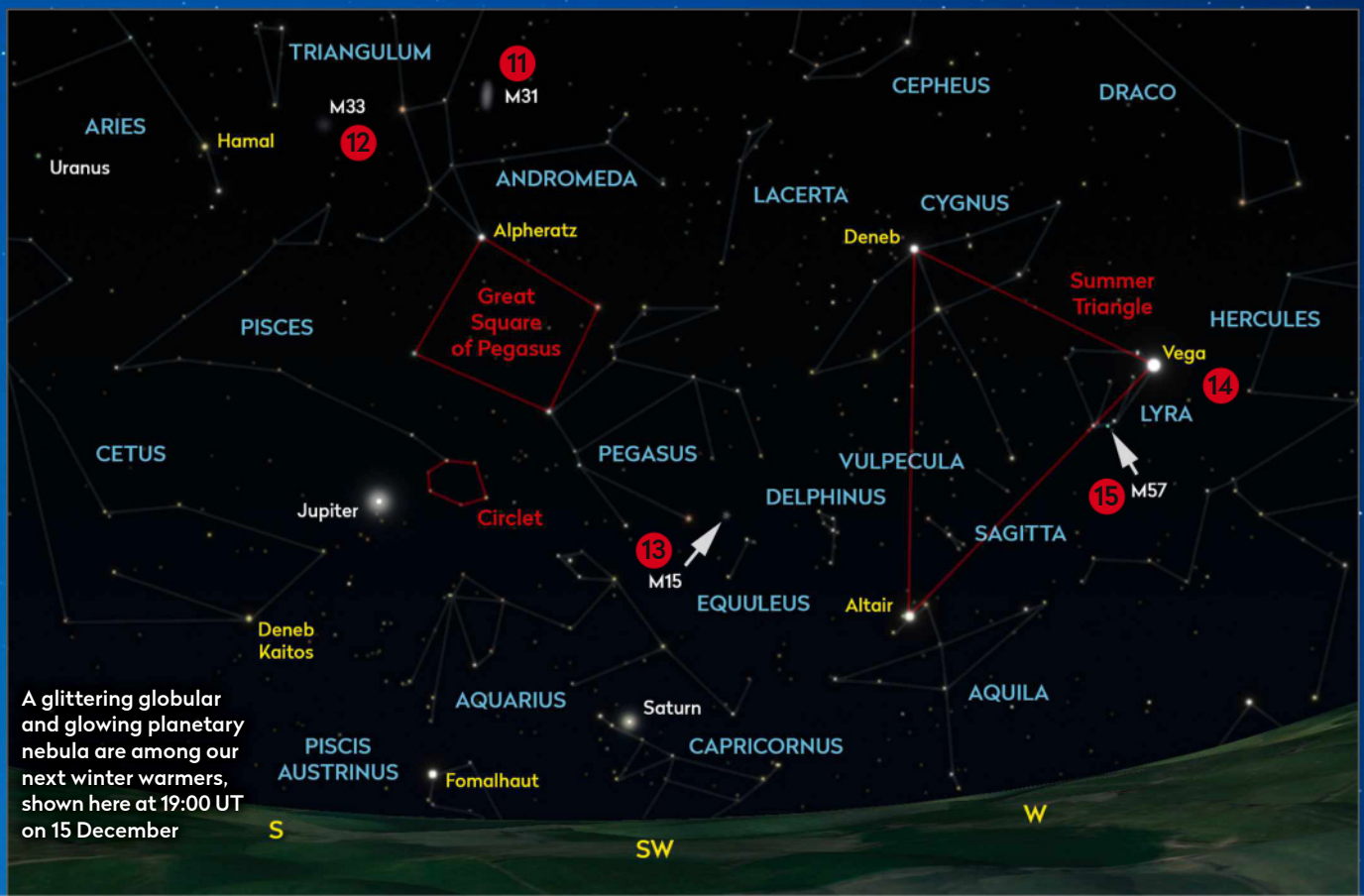
Globular clusters are huge balls of many thousands of stars and 6th-magnitude M15 is among the brightest and most observed globulars in the sky. It is 175 lightyears across but 34,000 lightyears away, so it looks like an out-of-focus star to the naked eye and a round smudge in binoculars. With a telescope it is a much more impressive, tightly-packed cluster of silvery-grey stars. ☐ **SEEN IT**

14 Vega

One of the three strikingly bright stars that make up the famous Summer Triangle asterism, Vega is still clearly visible in the sky over the festive period. At mag. +0.03, Vega is the fifth-brightest star in the whole sky. You'll find it shining low in the west as the sky grows dark, a beautiful blue-white spark of light. By midnight it will be almost scraping the horizon, but then it will start to climb higher again, never quite setting. ☐ **SEEN IT**

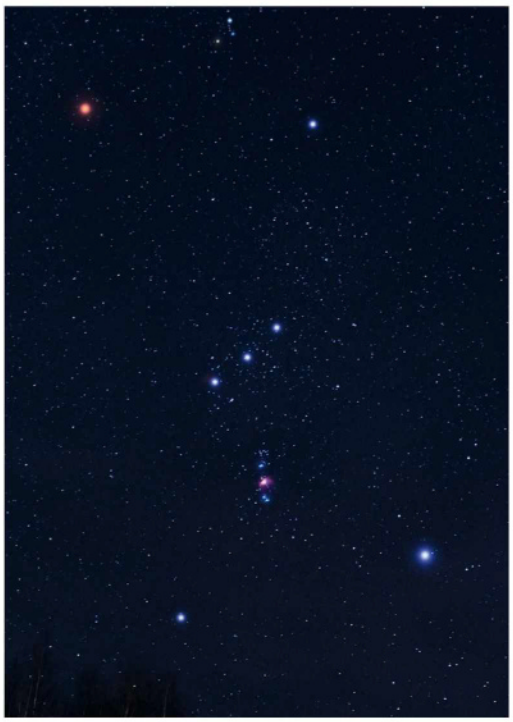
15 M57

Just under 7° away from Vega, planetary nebula M57 is famously known as the Ring Nebula because of its smoky, ring-like appearance through a telescope. Planetary nebulae are the results of dying stars puffing off their outer layers, and while there are larger examples elsewhere in the sky, M57 is greatly loved for its beautiful colours. It looks like an out-of-focus green star through binoculars. ☐ **SEEN IT** ▸



A glittering globular and glowing planetary nebula are among our next winter warmers, shown here at 19:00 UT on 15 December

With so much to explore, Orion is the gift that keeps giving. View shown at 22:30 UT on 15 December



16 Orion

Considered by many to be the most handsome and dramatic constellation in the sky, Orion, The Hunter's starry hourglass dominates the view throughout December. By 8pm all its brightly-coloured stars are clear of the horizon, shining like jewels low in the east. Ruddy mag. +0.6 Betelgeuse and fierce blue-white mag. +0.3 Rigel shine diagonally opposite each other, on either side of the famous Belt. **Turn to page 72** for more advice on observing this wonderful constellation. ☐ **SEEN IT**

17 Orion's Belt

This diagonal line of three icy stars pulled tightly around Orion's waist is one of the most famous asterisms in the sky and a striking sight as they rise above the horizon on frosty December nights. The three are all around second magnitude (as bright as Polaris). Through binoculars you'll see many fainter stars shining around them. ☐ **SEEN IT**

18 Orion Nebula

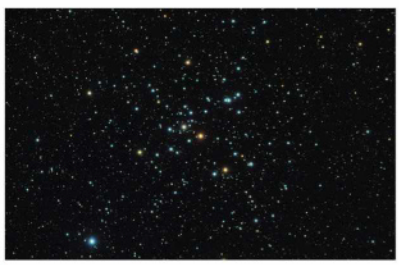
There are many bright nebulae in the sky, but the Orion Nebula, M42, is in a class of its own. Glowing in the centre of Orion's Sword, which hangs down from the left side of the Belt, the nebula is a ghostly patch to the naked eye. Binoculars show it as a feathered, grey smudge, while telescopes reveal it to be a beautiful cloud of grey-green light, with dark notches and streamers silhouetted across it. ☐ **SEEN IT**

19 Sirius

The brightest star in the sky, Sirius blazes to the lower left of Orion. Because it never rises very high in the sky from mid-latitudes like the UK, it is always seen through the turbulent air above the horizon and so appears to flash and scintillate dramatically through the long winter nights, glinting like a finely-cut diamond. Seen through a telescope it is literally a dazzling sight. ☐ **SEEN IT**

20 M41

Lying only 4° south of brilliant Sirius, this mag. +4.5 open star cluster is often overlooked, but it is as lovely a sight as many better-known clusters. Around 100 stars can be seen with the naked eye and it is very pretty through binoculars. ☐ **SEEN IT**



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21 M44

Also known as the Beehive Cluster, M44 is not high in the sky until after 10pm on December evenings, but it is worth waiting for. Very obvious to the naked eye as a large smudge of stars in the centre of Cancer, at only 577 lightyears away M44 is one of the nearest star clusters to us. It contains around 1,000 stars, hundreds of which can be seen through binoculars or a small telescope. ☐ **SEEN IT**

22 The Hyades

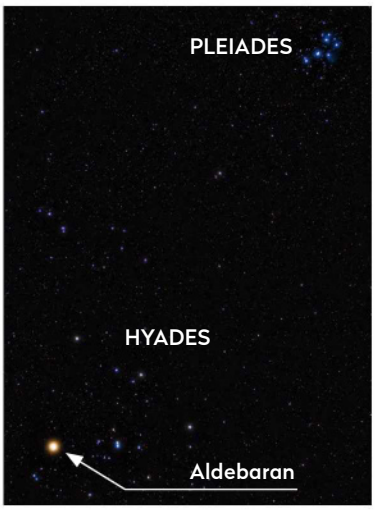
Representing the sharp horns of Taurus, the Bull, this V-shaped star cluster is obvious to the naked eye to the upper right of Orion. Lying on its side like a mathematical 'greater than' symbol, the Hyades contains several hundred stars. Its brightest star, the orange-hued Aldebaran, is not actually part of the cluster; it just happens to lie in the same direction as seen from Earth. ☐ **SEEN IT**

23 The Pleiades

Many observers believe the Pleiades, M45, is the most beautiful star cluster in the sky. To the unaided eye it is an eye-catching knot of seven blue-white stars – hence its popular nickname 'The Seven Sisters'. Binoculars reveal dozens more stars dotted around the seven brightest, and through a telescope the Pleiades is a spectacular spray of stars: so many that they spill out over the edge of even a low-power eyepiece's field of view. ☐ **SEEN IT**

24 Aldebaran

Rising in the east early on Christmas Eve night and throughout December is the red giant star Aldebaran. It's found in Taurus and is known as the 'red eye of the bull'. The star appears to be in the Hyades cluster but is actually much closer to Earth. Find it by extending the line of Orion's three Belt stars up and to the right. Aldebaran is also part of the Winter Hexagon asterism: it's a great jumping-off point to star-hop to some wonderful widefield targets. ☐ **SEEN IT**



A Christmas Day get-together as the Moon, Mercury and Venus mingle. View at 16:45 UT

25 Mercury, Venus and a shining crescent Moon

On Christmas Day afternoon, just as the Sun sets, catch the brief but lovely sight of a gathering not of three wise men, but three shining bodies just above the southwest horizon: the silver sliver of a crescent Moon and the planets Mercury and Venus. They will be visible to the naked eye, but much more obvious through binoculars, and in the same field of view. Venus will be the brighter of the planets, with fainter Mercury just under 4° away. You should also be able to see the unlit part of the Moon's face glowing a soft lavender hue. This is 'Earthshine', sunlight that has been reflected off Earth and onto the Moon's surface, a stunning sight through binoculars and small telescopes. ☐ **SEEN IT**

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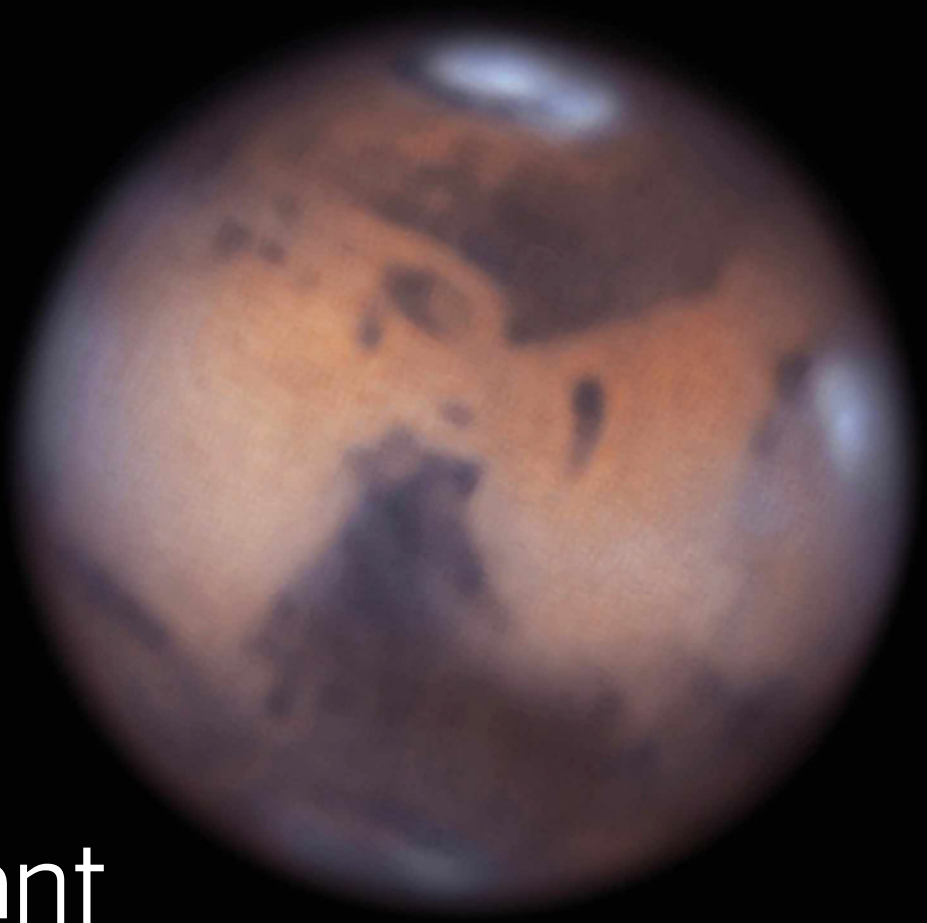


This month the Red Planet will be closer to Earth than at any time until 2033, promising great views of its surface

Magnificent MARS at its best

As the Red Planet makes its closest approach, reaches opposition *and* is occulted by the Moon, this really is Mars season! **Charlotte Daniels** helps you make the most of it

Seeing Mars through the eyepiece is always an unforgettable experience – whether it's the first time or you're revisiting an old friend. When conditions are right and you get a clear view, it's almost as if you can reach out and touch the planet on the other side of the telescope. Planetary observing can throw up challenges of course. We are at the mercy of a number of conditions: distortions from Earth's atmosphere, the brightness of the planet's disc and its proximity to the horizon, and even the planet's own weather can all affect the view we get, particularly for our rocky red neighbour Mars.

Charlotte Daniels is an astronomy journalist and experienced astrophotographer

Nevertheless, don't let this stop you taking advantage of the planet being well-placed in the sky, because this December brings the best conditions for viewing Mars until January 2025! On 1 December, it makes its closest approach to Earth. Then on the morning of 8 December, not only will it be at opposition but it will also be occulted by the Moon. But those aren't the only opportunities to see this vibrant body, so join us as we tell you how to get the most out of Mars throughout December. ▸

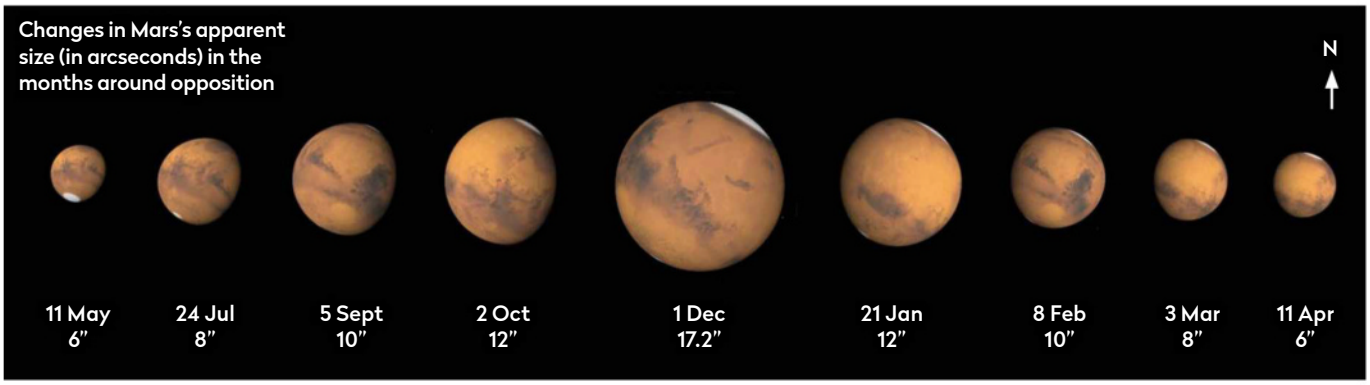
PETE LAWRENCE

Mars at its biggest and brightest

The planet gets its time to shine as it sits directly opposite the Sun

Oppositions are exciting opportunities to see planets in a whole new light. They occur when a planet lies directly opposite the Sun, while we're nestled in between. For this opposition, the arrangement is such that Mars rises at sunset and stays illuminated throughout the night before setting at sunrise – meaning there's plenty of time to dodge clouds and dig out your telescope or binoculars for a look.

During opposition season, Mars's full disc is illuminated by the Sun, granting us the best, most complete surface views. It can be a fickle planet to capture, its appearance changing drastically depending on its proximity, position and brightness. At its closest approach on 1 December it will appear the largest it has been since 2020, reaching an apparent size of 17.2 arcseconds across, dropping only to 17.1 at opposition on 8 December. At midnight, when it reaches its highest point above the horizon (30°), it will reach mag. –1.9, brighter than Saturn in the sky.




Look out for Mars and other planets in the months ahead

Mars season

Mars is on display for months after opposition

If the UK weather isn't kind this December, don't worry. Although it will be moving away from us, Mars isn't leaving our skies for a while. Small refractors will still be able to see some surface details until the end of February 2023. After that, its angular diameter will mean it is more suitable for longer-focal-length reflectors until about April 2023. It will be visible until summer 2023, but its brightness and size will be much diminished.

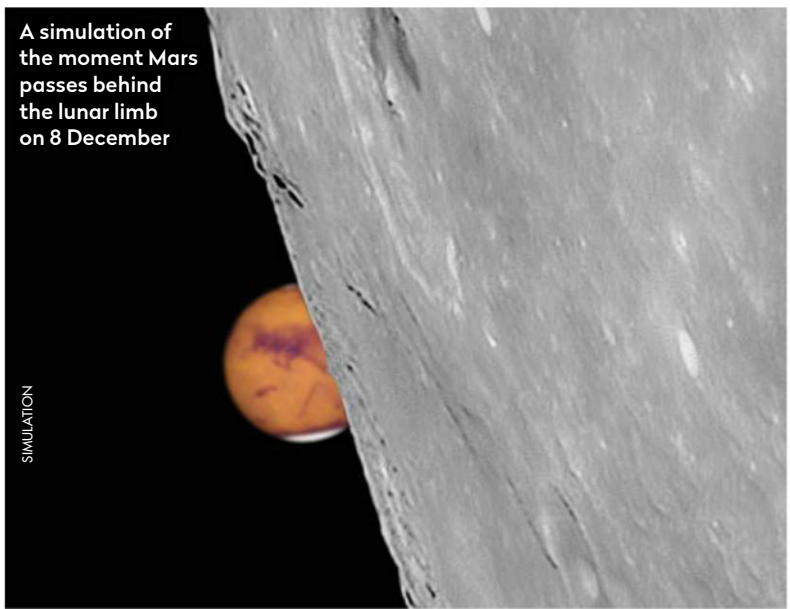
It's also a good time to see the other planets too, with Saturn, Jupiter, Neptune and Uranus lined up in the night sky, so why not put your planetary setup through its paces and see how many you can observe or capture in one night?

Occultation by the Moon

Mars will disappear from view for an hour on 8 December

Not only is Mars the largest and brightest it has been for over two years, but in the early hours of 8 December we will also see it appear to vanish behind our Moon. At around 04:57 UT, observers in the UK can witness the 100%-illuminated full Moon passing in front of Mars.

The planet will take around 36 seconds to disappear, before reappearing about an hour later at 05:57 UT. These timings are from the centre of the UK, but exact timings will depend on your location, so it's wise to start observing earlier. While a bright Moon will wash out surface details on the approaching planet, it will provide a stunning view as Mars will be visible right up to the illuminated lunar edge. **Turn to page 46 to find out more about the occultation.**



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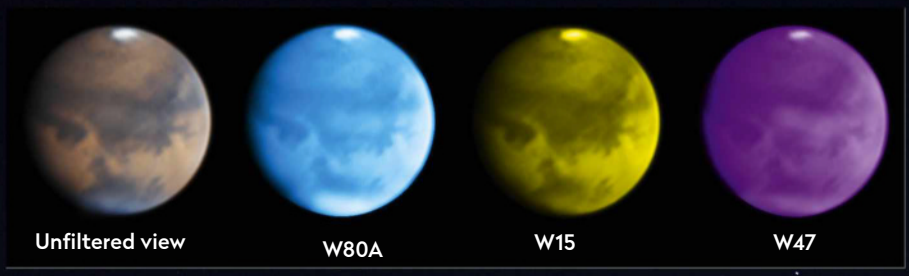
Get your best view of the spectacle

Magnification, aperture, filters and seeing conditions all play a part

At the start of December, Mars is in the constellation of Taurus. Look to the east and then the south throughout the evening and it will be hard to miss. Mars can be enjoyed through almost any telescope; even a short, small-aperture refractor reveals details on the red disc. Adding a Barlow lens will increase the focal length and magnify the image, allowing you to pick up further details, including dark and light patches (known as albedo features). But the ability to magnify is limited by seeing conditions: the greater the magnification, the more disruptive atmospheric turbulence is. A (very) general rule of thumb for magnification is 20x to 30x per inch of aperture, although in reality it is very much down to the weather on the night.

A good-quality, longer-focal-length refractor could offer more surface detail, including some cloud structure or the polar caps. It's worth noting that refractors are likely to require high-powered eyepieces in addition to a Barlow lens to get detail, adding more glass, which can end up distorting views or adding chromatic aberration.



▲ **Wratten filters will make Martian dust clouds easier to see than in an unfiltered view (top left). Use light blue (W80A), yellow (W15) or violet (W47) filters to enhance definition**

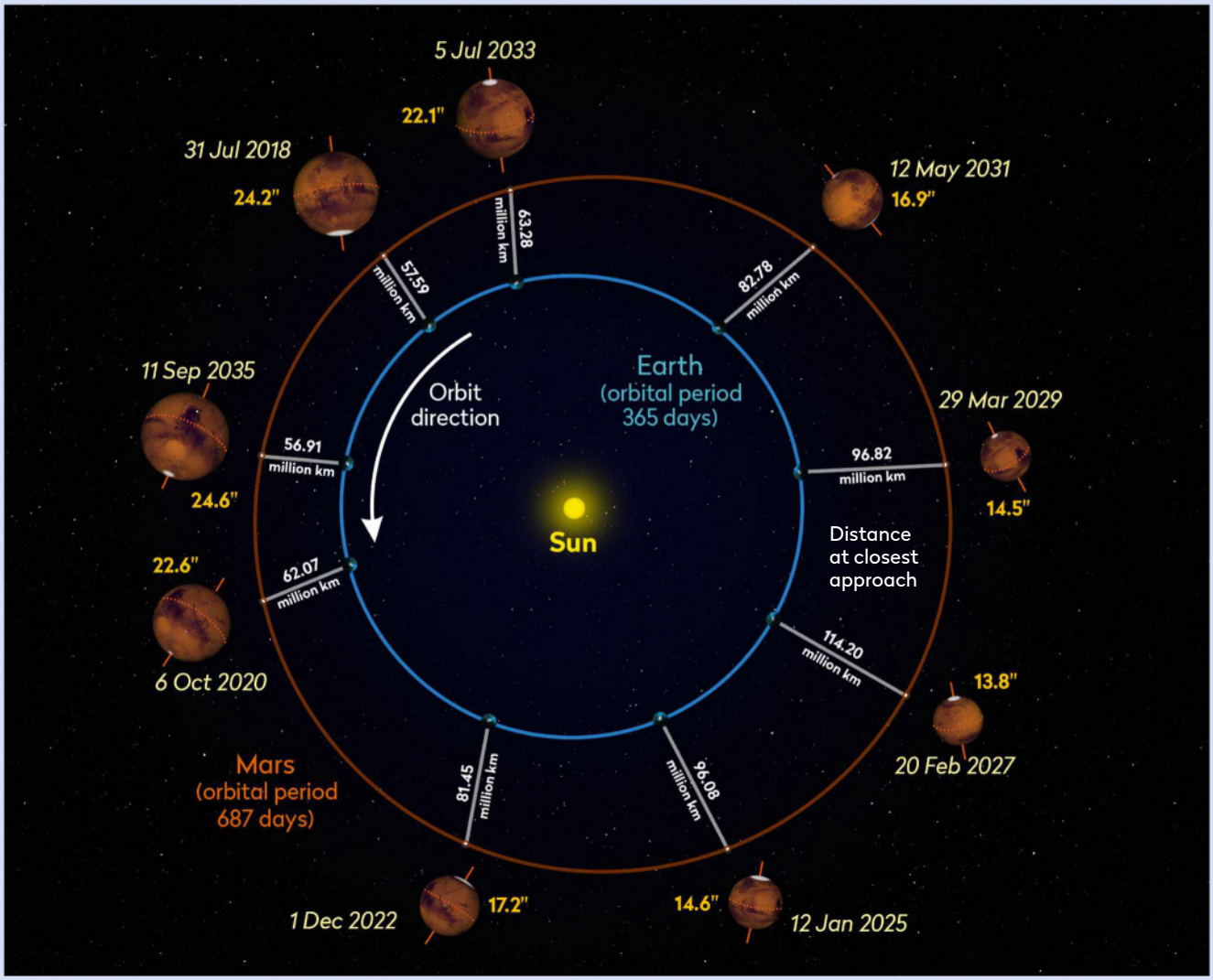
Newtonian reflectors offer longer focal lengths and allow us to get closer. Catadioptric tubes, such as Schmidt- and Maksutov-Cassegrains, are longer still and allow the use of lower-powered eyepieces to achieve the same magnification. Lower-power eyepieces are generally easier to view through and provide better eye relief over higher powers. We suggest starting off with a low-powered eyepiece and stepping up to the point where views stop improving.

In all cases, coloured filters, which tend to screw into the base of an eyepiece, will help to boost surface contrasts. An orange filter is a good start as it neutralises the orange disc, allowing dark regions to stand out.

Don't assume that 8 December should be the only date in your diary to view Mars. The weeks around opposition will also be a particularly special time to catch the planet. Taking time to view it during the week before and the week after opposition should not only allow you to see changes to the disc features, but will also train your eyes as you acclimatise to Mars's surface.

It will also give you more chances for a prime viewing night as planetary observing very much depends on the atmospheric conditions here on Earth – and a clear night doesn't always equate to good seeing. Air humidity, damp, weather fronts and even the jet stream's relative position to you will have a significant impact on your session. If it's poor one night, stick at it! The next evening can be very different and provides a good opportunity to compare any extra details you might see as you get to know the surface. ▸

The long focal length of a catadioptric scope combined with a low-powered eyepiece is ideal for Mars close-ups



▲ **Earth and Mars during their closest approaches from 2018 to 2035, with the apparent diameter of Mars shown in arcseconds**

Mars's changing orbit

No two oppositions are equal – some bring the planet closer than others

Mars oppositions occur roughly every 26 months and are a great chance to catch this challenging planet's complex beauty. Not all oppositions are equal, however.

Both Mars's and Earth's orbits are elliptical, and each is gently affected by the gravitational pull of other planets, meaning that oppositions don't always take place when Mars is as its closest point to us. This month, Mars will make its closest approach to Earth on 1 December, reaching a mere 81.45 million kilometres away. So-called 'perihelic oppositions' – ones where Mars is extremely close to us – only happen every 15–17 years or so. Even then, some perihelic oppositions are exceptional. For example, Mars's opposition in 2003 occurred at the closest approach in almost 60,000 years, and won't be beaten until 2287! In short, any opposition is an opportunity you'll want to take full advantage of. The variations also affect the planet's apparent magnitude and the angular diameter of its disc. This year it will reach 17.2 arcseconds at closest approach, but in 2020 it was 22.6. At its next opposition in January 2025, Mars will only reach 14.6 arcseconds. 2022's opposition won't be beaten until 27 June 2033, when the planet's apparent size increases to 22.1 arcseconds.

Photographing Mars

Widefield or close-up, there are many ways to capture the Red Planet

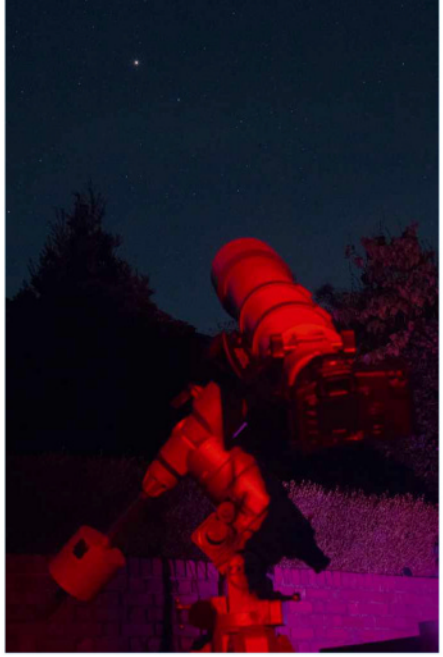
Imaging Mars can be as addictive as observing it. There are striking details to be resolved and, as December kicks off, we're looking forward to widefield planetary imaging opportunities.

Look for a night with good seeing when the air is stable. You won't need the kind of long exposures that nebulae require, so patchy clouds shouldn't put you off. Because of the planet's position relative to Orion and Taurus this month, it will form a beautiful orangey-red triangle with Aldebaran and Betelgeuse. Why not head out with your DSLR, wide-angle lens and a sturdy tripod to image this stunning arrangement? Set your exposure time to the longest you can achieve without star-trailing – for an approximate maximum exposure time divide 500 by the focal length of your lens or telescope. In terms of ISO, this will depend on the exposure time and camera model. Some will cope better than others at a high ISO. Start at 800 and work your way up.

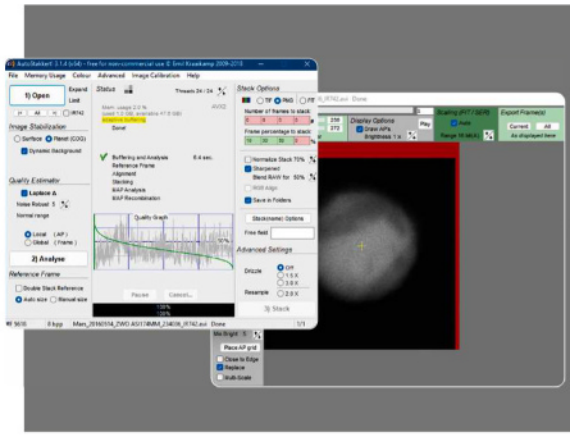
ALL PICTURES: PETE LAWRENCE

Of course, opposition season really means we want to capture serious surface detail. For that you'll need to dig out your tracking mount and longest-focal-length telescope. The good news is that DSLRs can still be used for planetary imaging as long as you can capture video, although preferably you would use a planetary camera as these capture higher frame rates, cutting through an unsteady atmosphere and giving a sharper image.

If using a DSLR, you will need a T-ring and adaptor that fits your telescope. You may still need a Barlow lens to enlarge your image, because Mars will still appear small. Given the tiny field of view of planetary cameras, it is often easier to locate the planet using an eyepiece, before popping the camera on. Due to the rotation of Mars, limiting videos to just a few minutes works best – say 2–4 minutes



▲ **To capture Mars in a wider field of view, a DSLR attached to a refractor fits the bill**



▲ **Use the free program AutoStakkert! to stack, rotate and convert your video frames**

for a planetary camera or 3–5 minutes for a DSLR. There are free stacking and processing software programs, including AutoStakkert! and RegiStax, which will convert video files into a single image.

If you're looking to capture the lunar occultation, then **we have a full guide on how to do that on page 76**.

Get a close look at the Martian surface

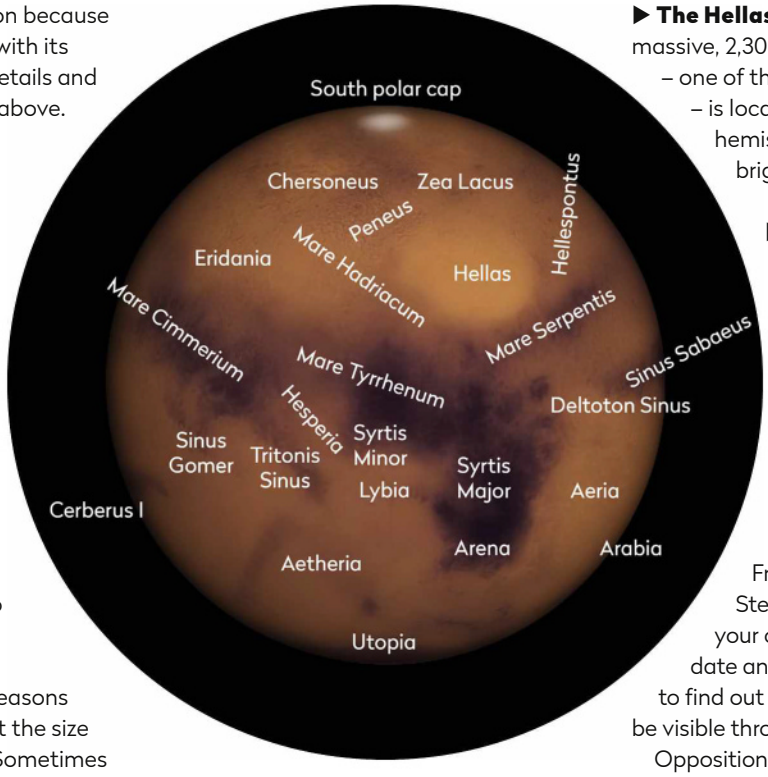
Now is the time to spy all the features visible on the Red Planet

Mars captures our imagination because it appears almost Earth-like with its polar caps, distinct surface details and occasional clouds swarming above. Its dusty composition, made up of iron and basalt, creates storms that cover the globe, obscuring its features for weeks. Meanwhile, Mars's rotation and axial tilt of around 25° means that throughout opposition season we can look forward to a variety of different views as the surface appears to shift slowly eastward.

From 1 December, keep an eye out for the following disc features, tracking them up to and past opposition:

▶ **Polar ice caps** Mars has seasons much like we do, which affect the size and shape of its polar caps. Sometimes its tilt means that only one is visible. However, for this opposition it might be possible to see both, depending on the seeing conditions.

▶ **Albedo features** This is one for smaller scopes as well as more advanced setups. Albedo refers to how much light is reflected from a surface: light and dark areas. Mars's dark patches are maria or seas, while the lighter areas are plains or continents, much like on our own planet.



▲ **The planet's most well-known regions. As Mars gets larger, it will be easier to spot its polar caps, deserts, seas and plains**

▶ **The Hellas impact crater** This massive, 2,300km-diameter circular basin – one of the largest in the Solar System – is located in Mars's southern hemisphere. It will appear as a bright reddish-orange patch.

▶ **Syrtis Major** This high plain of exposed volcanic rock is the largest dark area visible on Mars's disc. Its V-shaped form should be obvious, but clouds can change the appearance of these darker surface areas, altering their colour or obscuring them.

Free programs such as Stellarium will help you plan your observing. Simply set the date and time and zoom in on Mars to find out which surface features could be visible throughout the night.

Opposition is a great time to track and record your Mars observations, either in sketches or images. Given the close approach, opposition and occultation all occurring within eight days, we're viewing Mars in plenty of unusual circumstances. This also means that even if the weather isn't always favourable, we can all hope to catch a great view of the Red Planet.

ASTRONOMER'S GIFT GUIDE

SEGA HOMESTAR FLUX

Imagine enjoying the sky full of stars while sitting on your sofa. This dream can become reality with the Sega Toys series of **home planetariums**. Flux is the most powerful and most advanced model available to date. We take an incredibly popular planetarium design and refine it even further. Crafted in a satin-like finish, this powerful star projector is designed to be your first choice home planetarium. Brilliant glass lenses and our brightest LED to date, beautiful gift box, 30 plus optional discs... **Buy for £174** from **segatoys.space**

SMART GALAXY STAR PROJECTOR

Create a vision of space at home with this smart galaxy star projector designed to provide an out-of-this-world experience. The advanced device seamlessly integrates with android and iPhones while allowing you to choose from various colorful, therapeutic scenes. Set a timer to have your stars and nebula projecting on your ceiling, moving at a pace you've selected and prefer. Expect to feel like you're in space while enjoying the view of the adjustable moving nebula clouds and bright stars. The relaxing scenery will surely lift spirits while helping you create the perfect aesthetic in your personal space. **encalife.com**

Available as 8x42, 7x50, 10x50 and 12x50

SCAN ME

OSTARA ELINOR² BINOCULARS

The ideal night sky viewing binocular for any astronomer. New from Ostara the Elinor2 range of binoculars with upgraded optics and mechanical construction is a worthy successor to the original and highly successful award winning Elinor range, producing images that are out of this world! Available as 8x42, 7x50, 10x50 and 12x50. Every model is now available with a minimum of 15% discount from the retail price and FREE UK shipping. **binocularoutlet.co.uk | 0116 243 0967**

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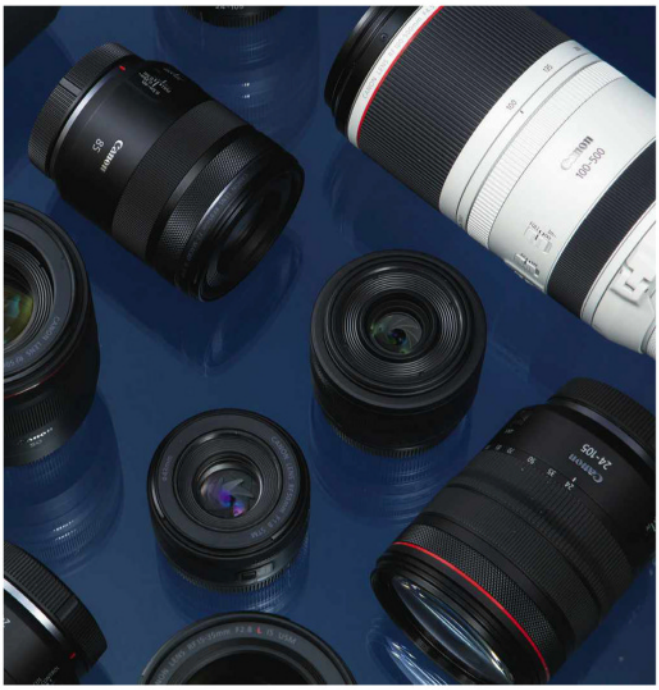

MPB

MPB is the platform to buy, sell and trade used photography and videography kit, including cameras, lenses and accessories. We are the simplest, safest and most sustainable way to buy, sell and trade in your camera equipment. Recirculating more than 350,000 items of used kit every year, we extend the life and creative potential of photo and video kit and making it more accessible and affordable. **mpb.com | sales@mpb.com**

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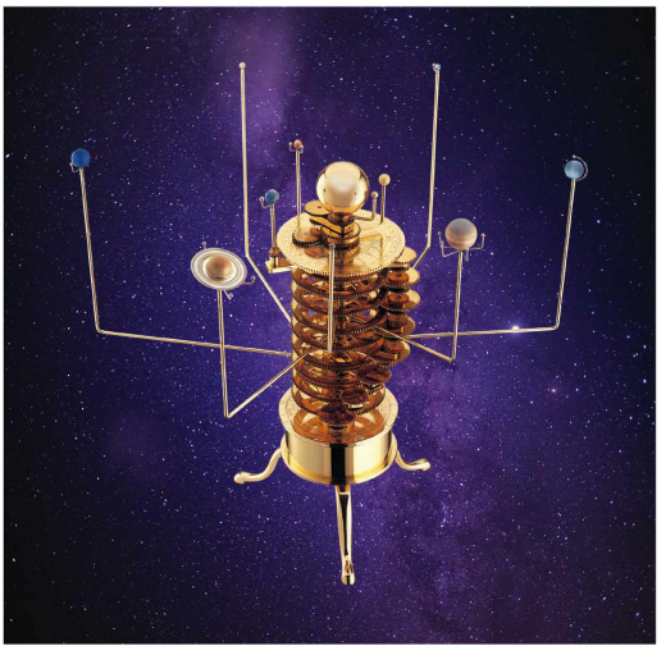
FLOATING MOON LAMP

The Floating 3D Moon Night Light Lamp levitates while illuminating your personal space. With three realistic moon colors to choose from, you can create an ambiance you'll love. Our magnetic levitation technology will leave you amazed, seeing the moon light floating and spinning automatically in mid-air freely without any support or contact. You'll feel calm and present with this amazing moon in your room. With a perfect sized diameter of 5.7 inches, coupled with 3D technology to make the lamp show a realistic lunar texture. The soft glow of the moon will be in your hands to soothe your senses. **encalife.com**



MODEL SOLAR SYSTEM

Inspired by the original Orrery and the classical scientific instruments of the seventeenth and eighteenth centuries, this mechanical model of the solar system is not only a work of art, but a functioning model of the solar system as it is known in the time that we are living. When complete, this beautiful model stands 37cm high with a span of 60cm at its widest point – a truly impressive museum-quality statement piece to display and use in your own home. £100 saving with code SOLAR100.
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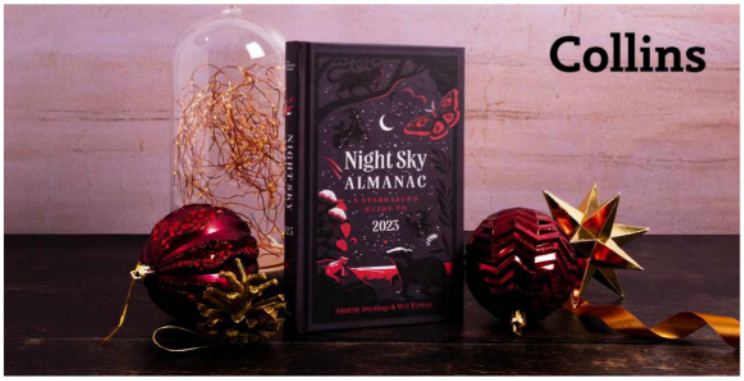
MUONIONALUSTA METEORITE WATCH

With this extra-terrestrial piece of history on your wrist, you'll have a slice of space with you wherever you go. The face of this watch is made from pure Muonionalusta meteorite making this timepiece the perfect gift for the person who has everything. It is engraved on the back with 'Muonionalusta Meteorite' and the watch is 3ATM water resistance, and has glow in the dark hands.Iron Nickel meteorites, like this one generally start as the very core of a planet, the amazing Widmanstätten patterns (unearthly metallic grids in shimmering shades of grey and silver are seen when the meteorite is sliced) are formed only in the vacuum of space. This watch comes in an elegant presentation box complete with an information card and certificate of authenticity. **Made from:** Rhodium plated, Muonionalusta Meteorite face, leather wrist strap, stainless steel casement. Japanese Quartz movement. **Dimensions:** Watch Face 37mm Diameter. Leather Strap 16cm to 23cm. **Price:** £220.00. Use code **NIGHTSKY10** for a 10% discount. **marthajackson.co.uk/shop/meteorite**
enquiries@marthajackson.co.uk



GIFT A YEAR OF STARGAZING THIS CHRISTMAS

Wondering what to get for the astronomy enthusiast in your life? Whether they are aspiring or seasoned stargazers, there is a Collins Astronomy guide for them. Follow the progress of constellations with *Night Sky Almanac 2023*; plan stargazing sessions with *2023 Guide to the Night Sky* or explore the Universe with *Observing Our Solar System*.
collins.co.uk/astronomy

TAKE AN AUTOMATED TOUR OF THE NIGHT SKY

The Celestron NexStar 4SE computerised telescope has a fully automated GoTo mount with a database of 40,000+ celestial objects that will automatically locate and track objects for you. The four-inch aperture provides excellent light gathering ability, you can expect dazzling views of the Moon, planets and brighter deep sky objects such as the Orion Nebula. The simple to use fork arm design allows for breakdown into separate components for easy transport and quick assembly. Includes a free download of Starry Night astronomy software to help you plan your observations. RRP £749.99.
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BBC Sky at Night MAGAZINE

16-PAGE CENTRE PULLOUT

The Sky Guide

DECEMBER 2022

MARS DISAPPEARS AT OPPOSITION

Mars is occulted by the Moon on the same day it reaches its brightest

FESTIVE URSIDS

Enjoy the Christmas lights as the meteor shower peaks

CHRISTMAS COMET

C/2022 E3 ZTF a bino sight on 25 December

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- Asteroid Herculina in Orion and Taurus
- Planet Uranus occulted by the Moon
- Trapezium challenge – can you resolve it?

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

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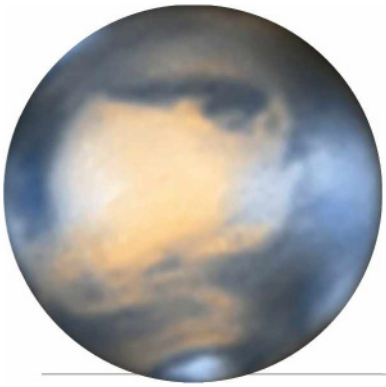
For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

DECEMBER HIGHLIGHTS

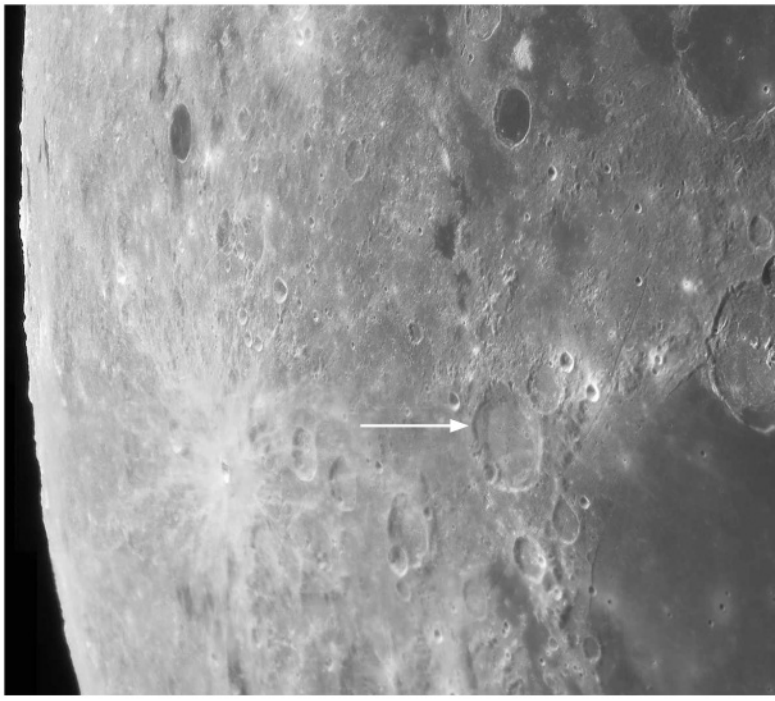
Your guide to the night sky this month



◀ Thursday 1

The planet Mars is closest to Earth today, presenting its largest apparent disc size of 17.2 arcseconds.

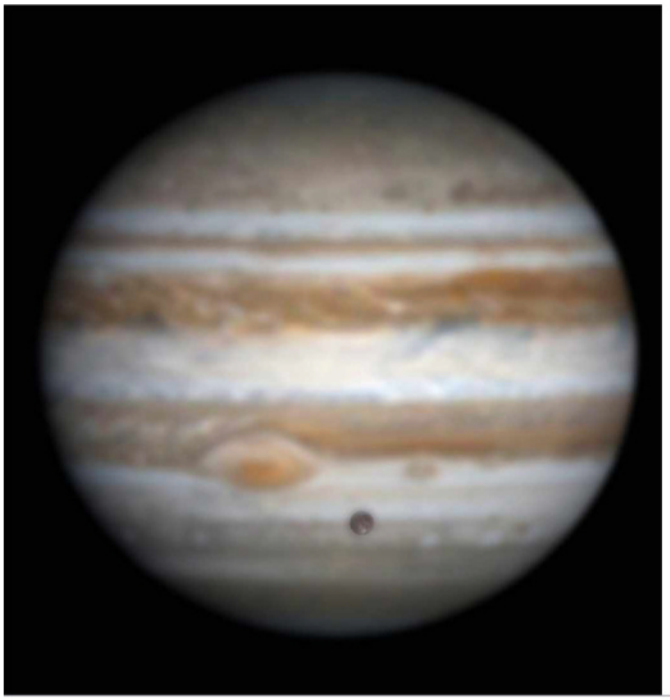
This evening's 54%-lit waxing gibbous Moon sits 3.8° west-southwest of mag. –2.4 Jupiter.



Thursday ▶ 8

The planet Mars is occulted by the full Moon. Disappearance occurs at 04:57 UT, with reappearance at 05:57 UT See page 46 for more.

Mars reaches opposition at 05:36 UT.



◀ Thursday 15

The giant moon Ganymede transits the planet Jupiter between 19:02 UT and 22:02 UT.

Sunday 18

The Moon rises just before 02:00 UT, making this a good time to start observing our Deep-Sky Tour on page 56. This month we're looking at objects in and around western Aries.

Wednesday ▶ 21

Mercury reaches greatest eastern elongation (20.1°), the mag. –0.4 planet visible above the southwest horizon shortly after sunset.

Today is the winter solstice and the longest night of the year.

Sunday 25

A treat for Christmas: comet C/2022 E3 ZTF is predicted to be viewable with binoculars, reaching mag. +8.0 today. The comet is currently inside the semi-circular constellation of Corona Borealis.

Monday 26

This evening's 15%-lit waxing crescent Moon lies 4.5° south of mag. +0.9 Saturn.

Thursday 29

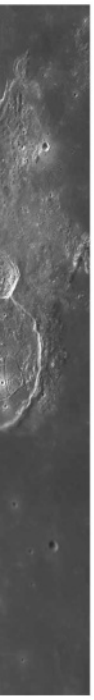
This evening's 48%-lit waxing crescent Moon is 5.4° east of mag. –2.2 Jupiter.

Just after sunset, mag. +0.6 Mercury appears 1.5° from mag. –3.8 Venus, low above the southwest horizon.

Friday 30

This evening's first quarter Moon will exhibit the popular clair-obscur effects known as the Lunar X and V. Peak visibility is around 21:00 UT.

PETE LAWRENCE X 7

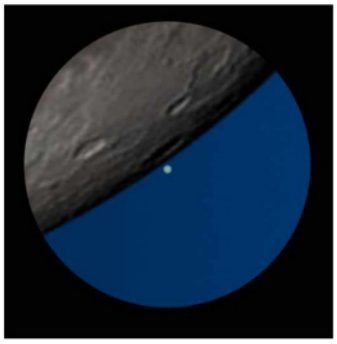


◀ Sunday

4 As midnight approaches tonight and into the morning of 5 December, our Moonwatch target, the 85km-diameter crater Mersenius will be revealed. See page 52 for more details.

Monday ▶

5 The Moon occults Uranus between 16:50 UT and 17:21 UT. Times correct for the centre of the UK and will vary slightly depending upon your location. See page 47 for more details.



Wednesday ▶

14 The annual Geminid meteor shower reaches peak activity around 13:00 UT. The night of 13/14 December presents the best opportunity for seeing a Geminid meteor, but a bright waning gibbous Moon will interfere.

Tuesday

20 With dark skies as the Moon approaches its new phase, the magnificent constellation of Orion is well-presented for viewing around midnight.

Thursday

22 With a new Moon tomorrow, this year's Ursid meteor shower is favourable, peaking around 22:00 UT.

Ganymede transits Jupiter just before it sets. View from 23:05 UT.

Friday

23 Ninth-magnitude comet C/2020 V2 ZTF is just 4° from Polaris this evening.

Saturday

24 Mag. –0.3 Mercury, –3.8 Venus and a slender 2%-lit waxing crescent Moon form an attractive triangle, visible shortly after sunset low above the southwest horizon.

Saturday

31 As the New Year approaches, bright Mars sits north of the Hyades open cluster, 8° north of mag. +0.8 Aldebaran (Alpha (α) Tauri). It is also located 9° east of the Pleiades.

Family stargazing

A very rare lunar occultation of Mars occurs in the early hours of 8 December. Disappearance of the planet is around 04:57 UT, so careful planning and an early night before will be required. Aim to rise around 03:00 UT. The Moon will be full and obvious, as Mars should be too, appearing to the left of it. The event can be enjoyed with the naked eye, binoculars or through a telescope if you have one to hand. Reappearance of Mars occurs around 05:57 UT. Make a friendly game out of its reappearance by seeing who can spot Mars first! **bbc.co.uk/cbeebies/shows/stargazing**

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

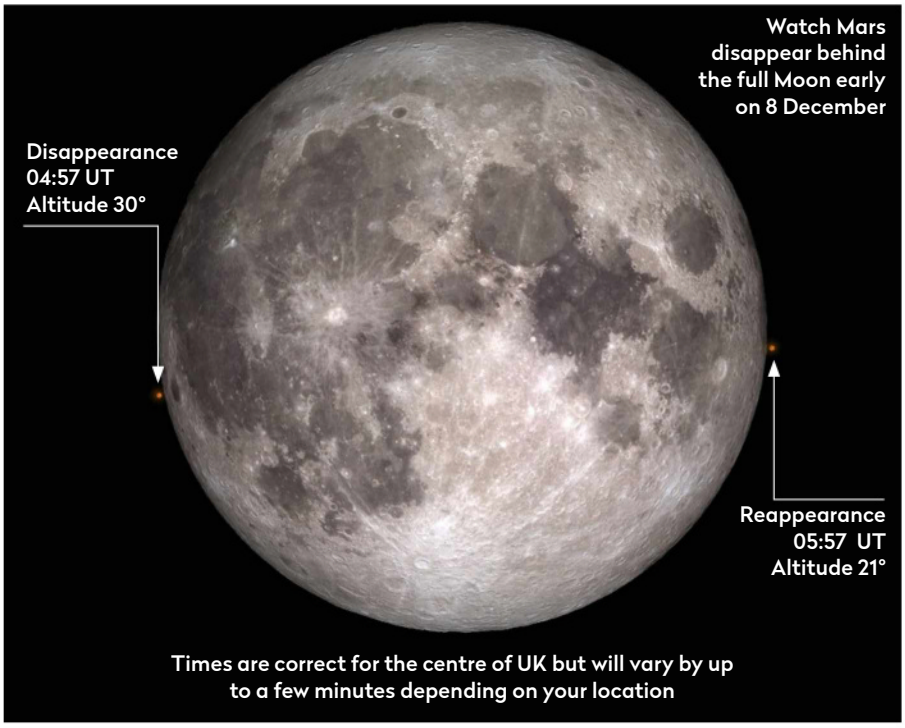
GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **bit.ly/10_easylessons** for our 10-step guide to getting started and **bit.ly/buy_scope** for advice on choosing a scope

DON'T MISS

Mars disappears at opposition

BEST TIME TO SEE: 8 December, 04:30 UT–06:30 UT



The Moon passes in front of Mars on the morning of 8 December in an event known as a lunar occultation. Although the Moon appears large, bright and dominant when in the night sky, its size is deceptive and in reality, its apparent diameter is pretty small at 0.5° across.

As it appears to travel around the sky over the course of a month, the Moon frequently passes in front of dim stars. Occultations of medium-bright stars occur too, but these are less frequent, and occultations of bright stars are uncommon enough to be quite special. But lunar occultations of planets are rare and to catch one is very special indeed.

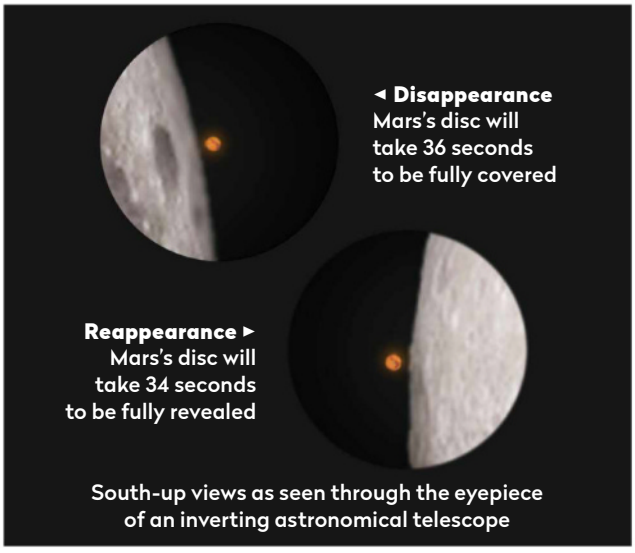
You'll frequently hear the Moon described as our nearest neighbour in space, orbiting at an average distance of 384,400km. This relatively close proximity introduces an effect known as parallax and means that when viewed from locations that are widely separated, the Moon's position against more distant background objects appears to shift. From the UK, we've been lucky in terms of lunar occultations of planets in 2022. In September the Moon moved in front of Uranus, an event that repeats this month on 5 December (see opposite).

On the morning of 8 December, we get our third occultation of a planet when Mars will be hidden by the full Moon. Mars reaches opposition on 8 December too, when it will be opposite the Sun in the sky. This is also why the Moon is full on this date; it too is technically at opposition.

Mars will be shining at mag. –1.9 and presents a disc 17.1 arcseconds across. Consequently, it takes the Moon an extended time to fully cover and subsequently reveal Mars.

From the centre of the UK, disappearance begins at 04:57 UT, Mars taking around 36 seconds to fully disappear. Reappearance begins at 05:57 UT, the Red Planet also taking 34 seconds to reappear. Now remember the mention of parallax. Your location within the UK will affect the timings slightly, varying them by up to a few minutes. This is because locations away from the UK's centre make the Moon appear in a slightly different position relative to Mars.

The best observing strategy for this event is to start watching from 20 minutes or more before the stated event times, to make sure you don't miss anything. The event is suitable for viewing with the naked eye, binoculars or a telescope. A mid-power magnification will give an amazing view, showing the Moon well and Mars as a tiny disc next to it.



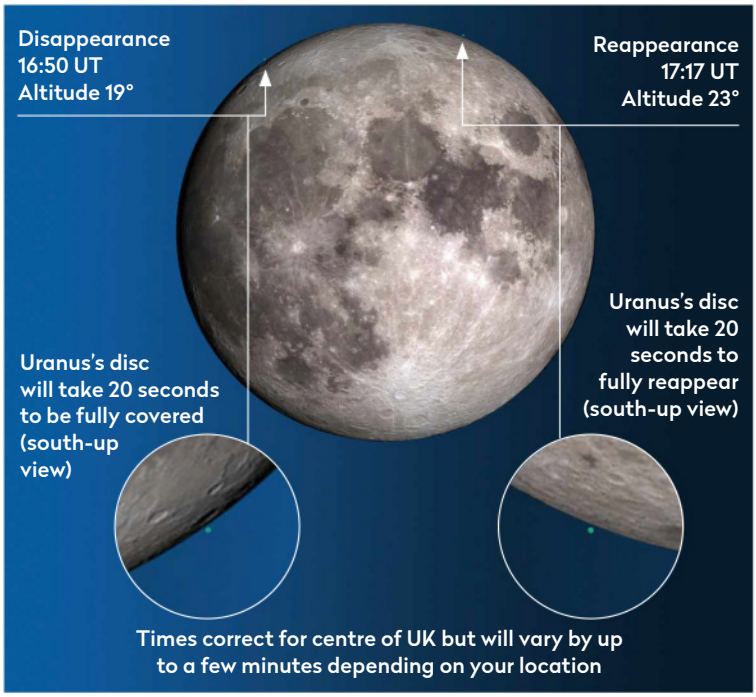
▲ **The occultation lasts around an hour. Mars's 17.1-arcsecond disc will take several seconds to fully disappear and reappear**

ALL PICTURES: PETE LAWRENCE

Lunar occultation of Uranus

BEST TIME TO SEE: 5 December, 16:20 UT–17:50 UT

As a prelude to the lunar occultation of Mars on the morning of 8 December, the planet Uranus will also be hidden by the Moon on the evening of 5 December. This is the second lunar occultation of Uranus this year and, in terms of timing, the least favourable of 2022's three lunar occultations of planets. The Moon will be in an advanced waxing phase at the time of the occultation, 94% lit. This will mean it is the dark preceding limb that hides Uranus, with the planet then reappearing from behind the bright following limb.



▲ Uranus will disappear behind the Moon's northern limb on 5 December

Disappearance from the centre of the UK is at 16:50 UT, 50 minutes after sunset, when the sky will be darkening but not fully dark. Shining at mag. +5.6, Uranus will be harder to see because of this. Reappearance is better-timed, but not by much, Uranus reappearing at 17:17 UT from behind the Moon's northeast limb. The sky will still be twilit, but with a small or medium telescope it should be possible to spot the planet pop out from behind the Moon.

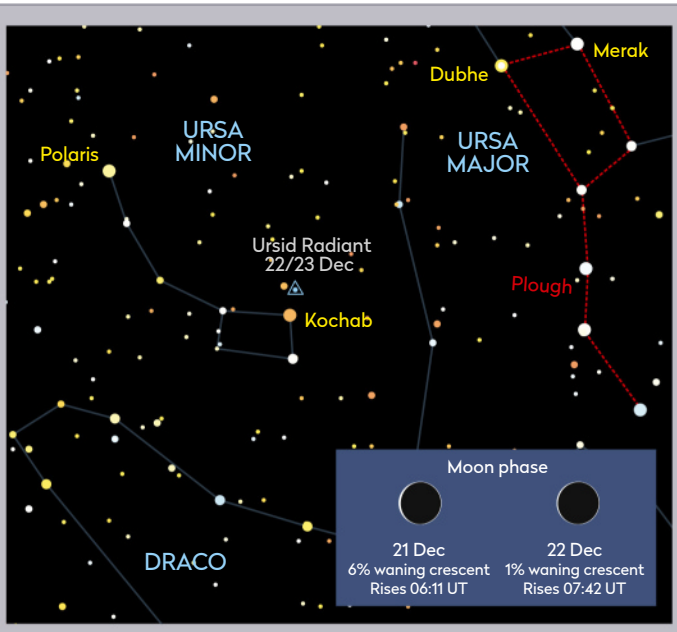
Uranus is a distant world and appears quite small, even through a large telescope. With an apparent diameter of 3.8 arcseconds, it doesn't take the Moon very long to cover it. However, unlike the 8 December event involving Mars, in this occultation Uranus disappears close to the Moon's northern limb. As a consequence, the disappearance and reappearance occur at a shallower angle to the Moon's edge and it takes a fraction longer to cover Uranus than it would if the event were more square-on.

Favourable Ursids

BEST TIME TO SEE: Night of 22/23 December

The full Moon on 8 December means that there will still be a bright lunar presence in the sky five days later when the Geminid meteor shower reaches its peak on the night of 13/14 December. Unfortunately that 70%-lit waning gibbous Moon will have a detrimental effect on the number of Geminid meteors that can be seen. However, there is another shower that peaks in December which, while it may not have the pazazz of the Geminids in terms of peak hourly rate, is still a worthy event to observe.

The Ursid shower has its radiant position close to the star Kochab (Beta (β) Ursae Minoris). Although not optimal, this isn't too bad. The shower has a typical peak rate of 10 meteors per hour and, like the Quadrantids which peak early in January, the maximum activity period is short. For the best views you need to be observing within 12 hours of the peak, which this year is expected around 22:00 UT on the night of 22 December. That bright Moon that will hinder Geminid meteor observation will be completely out of the way on this date, being new at 10:17 UT on 23 December. Consequently, if the sky is clear on the evening of 22 December, this is a good year to try to record some Ursid meteors.



▲ A new Moon means no interference for this year's Ursids peak

THE PLANETS

Our celestial neighbourhood in December

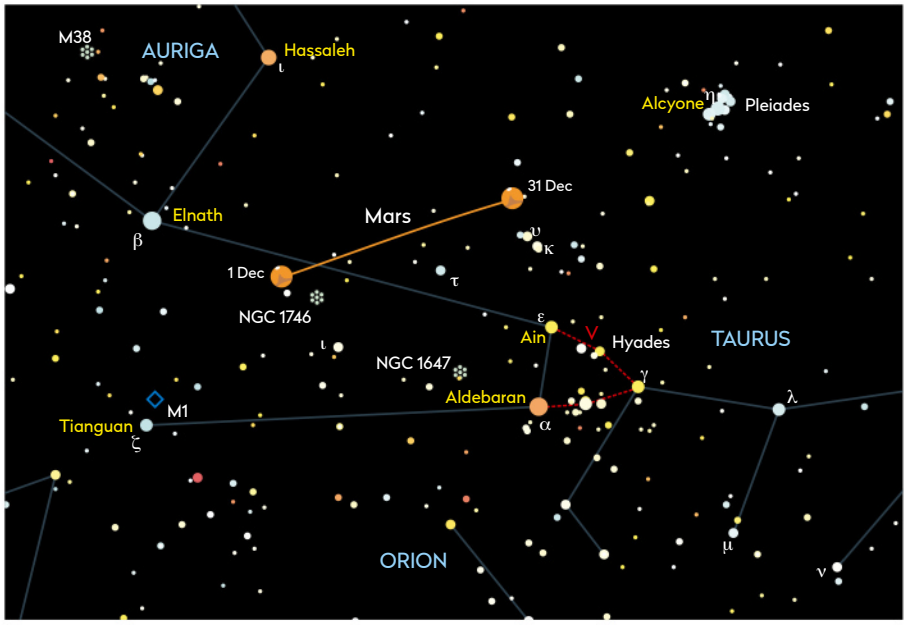
PICK OF THE MONTH

Mars

Best time to see: 1 December, 00:30 UT
Altitude: 62°
Location: Taurus
Direction: South
Features: Light deserts with darker exposed rock, polar caps, weather
Recommended equipment: 75mm or larger

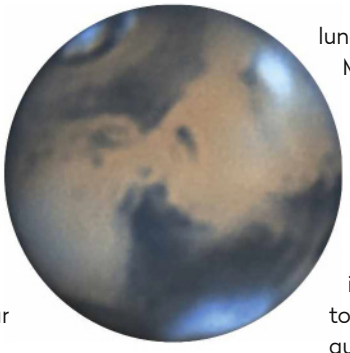
Mars reaches opposition on 8 December. Around this time the planet appears at its brightest and largest in terms of apparent size. Mars is closest to Earth on 1 December, when it appears as a mag. –1.9 object among the stars of Taurus. On this date Mars has an apparent diameter of 17.2 arcseconds. At this size, albedo features – features that show different reflectivity – can be seen quite easily. The most obvious are the dark, exposed rocky regions on the planet that contrast well with the surrounding lighter deserts. In addition, the planet is sideways-on to us at present, potentially giving us a view of both polar regions. The southern polar cap will probably be absent, it being summer in Mars's southern hemisphere. The northern cap will be augmented by a large cloud shroud, known as a polar hood.

PETE LAWRENCE X 2



▲ **Around opposition, Mars journeys through Taurus near the beautiful Hyades and Pleiades**

When observing Mars, it pays to be patient and allow your eyes to get used to the view. It's quite common to look at the planet and see nothing but a bright orange-pink disc through the eyepiece of a telescope. However, as your eye becomes accustomed to the light, the subtle surface features become more obvious.

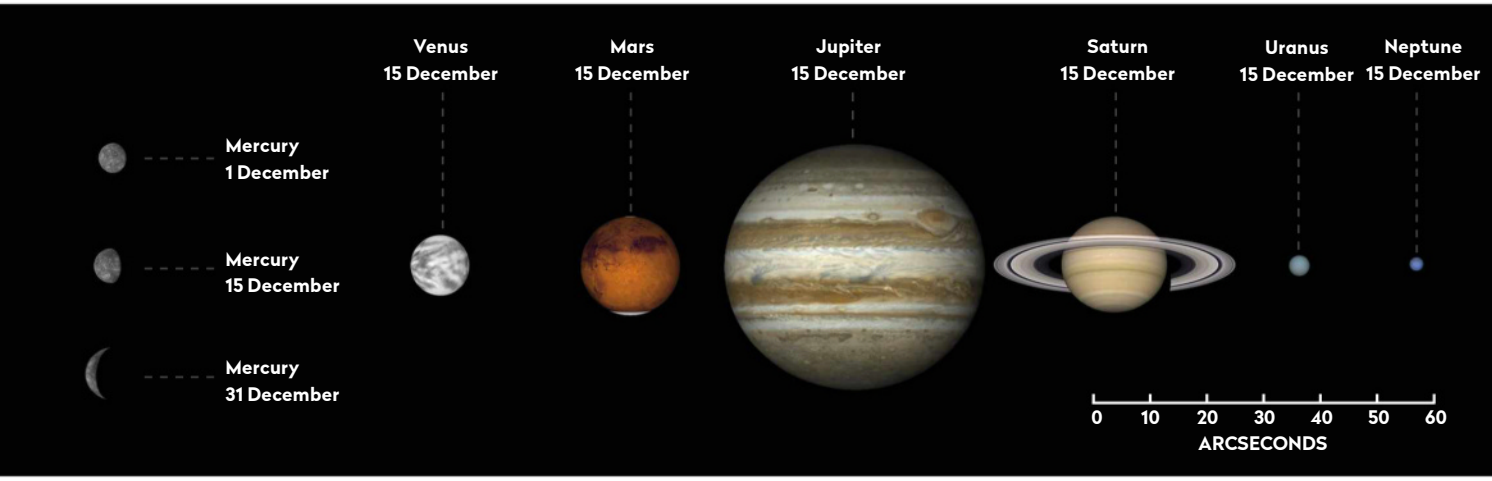


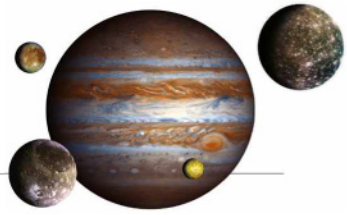
▲ **The north and possibly even the south polar cap will be visible**

On opposition day, 8 December, Mars will be occulted by the full Moon – the lunar phase that sees the Moon also at opposition. Mars disappears behind the lunar limb at 04:57 UT, reappearing back into view one hour later at 05:57 UT. On 31 December, although it will have faded slightly to mag. –1.2, Mars will look quite resplendent against the stars of Taurus, near to the Pleiades and Hyades open clusters and 8° to the north of orange-hued Aldebaran (Alpha (α) Tauri).

The planets in December

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see:
29 December, 30 minutes after sunset
Altitude: 5° (low)
Location: Sagittarius
Direction: Southwest
A mag. –0.5 evening object, not well-positioned at the start of December when it sets with mag. –3.8 Venus, 30 minutes after the Sun. Greatest eastern elongation occurs on 21 December, Mercury appearing separated from the Sun by 20.1°. On this date it lies 5.4° from mag. –3.8 Venus, setting 80 minutes after sunset. On 29 December, mag. +0.6 Mercury and –3.8 Venus appear 1.5° apart, low in the southwest after sunset. On this date, Mercury sets almost 90 minutes after the Sun.

Venus

Best time to see:
31 December, 30 minutes after sunset
Altitude: 5° (low)
Location: Sagittarius
Direction: Southwest
A bright mag. –3.8 evening object, slowly pulling away from the Sun. Telescopically, it is at its least optimal, 10 arcseconds across and over 90% illuminated. Venus chases Mercury, catching up with it late in the month. A 2%-lit Moon sits below both planets on 24 December, very low just after sunset.

Jupiter

Best time to see:
1 December, 19:32 UT
Altitude: 35°
Location: Pisces
Direction: South
A magnificent evening planet. Shining at mag. –2.5 on 1 December, it is joined by a 62%-lit waxing Moon 3.5° away before they both set in the early hours of 2 December. A second lunar visit occurs on the evening of 29 December, this time from a 46%-lit Moon. It reaches its highest position in the sky, due south, under dark sky conditions for most of the month. On 31 December, it shines at mag. –2.2.

Saturn

Best time to see:
1 December, 17:15 UT
Altitude: 21°
Location: Pisces
Direction: South
A lovely 15%-lit waxing Moon sits 4.7° south of Saturn on the evening of 26 December. By the end of the month, mag. +0.9 Saturn sits 15° above the southwest horizon by the time darkness gets underway.

Uranus

Best time to see:
1 December, 22:20 UT
Altitude: 53°
Location: Aries
Direction: South
Mag. +5.7 Uranus is well-placed, due south at a dark-sky peak altitude over 50°. It is occulted by a 94%-lit waxing Moon on the afternoon of 5 December. It disappears at 16:51 UT under darkening twilight and could be tricky. Reappearance should be easier, occurring under darker conditions at 17:17 UT.

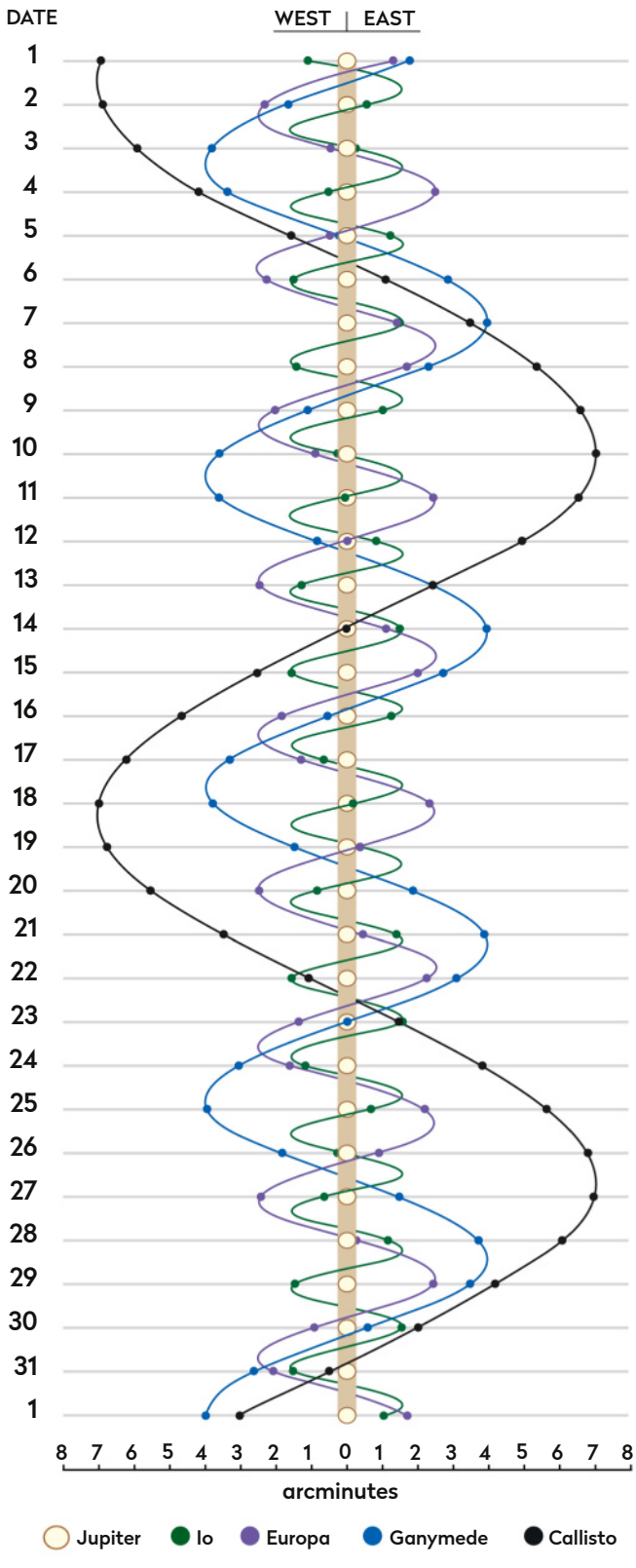
Neptune

Best time to see:
1 December, 19:00 UT
Altitude: 33°
Location: Aquarius
Direction: South
Mag. +7.9 Neptune manages to attain an altitude around 30° under dark-sky conditions all month. A 36%-lit Moon sits 3.7° southwest on 28 December. Mag. –2.2 Jupiter remains close to Neptune too, 8° east at the end of the month.

More **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: DECEMBER

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically over the month, as shown on the diagram. The line by each date represents 00:00 UT.



THE NIGHT SKY – DECEMBER

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Cricket — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW
- MILKY WAY

CHART: PETE LAWRENCE

When to use this chart

1 December at 00:00 UT
15 December at 23:00 UT
31 December at 22:00 UT

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in December*

Date	Sunrise	Sunset
1 Dec 2022	08:03 UT	15:55 UT
11 Dec 2022	08:16 UT	15:51 UT
21 Dec 2022	08:24 UT	15:52 UT
31 Dec 2022	08:26 UT	16:00 UT

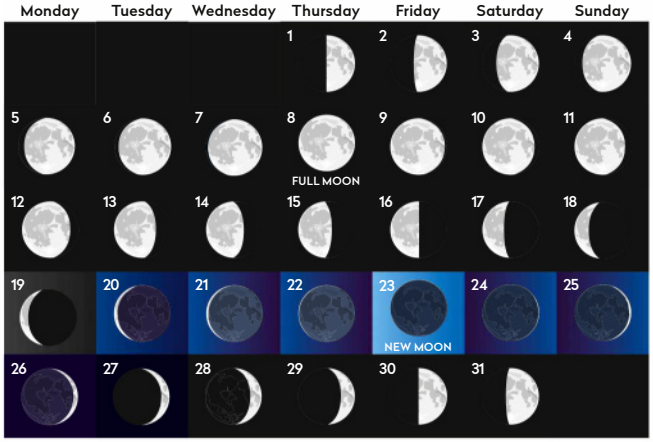
Moonrise in December*

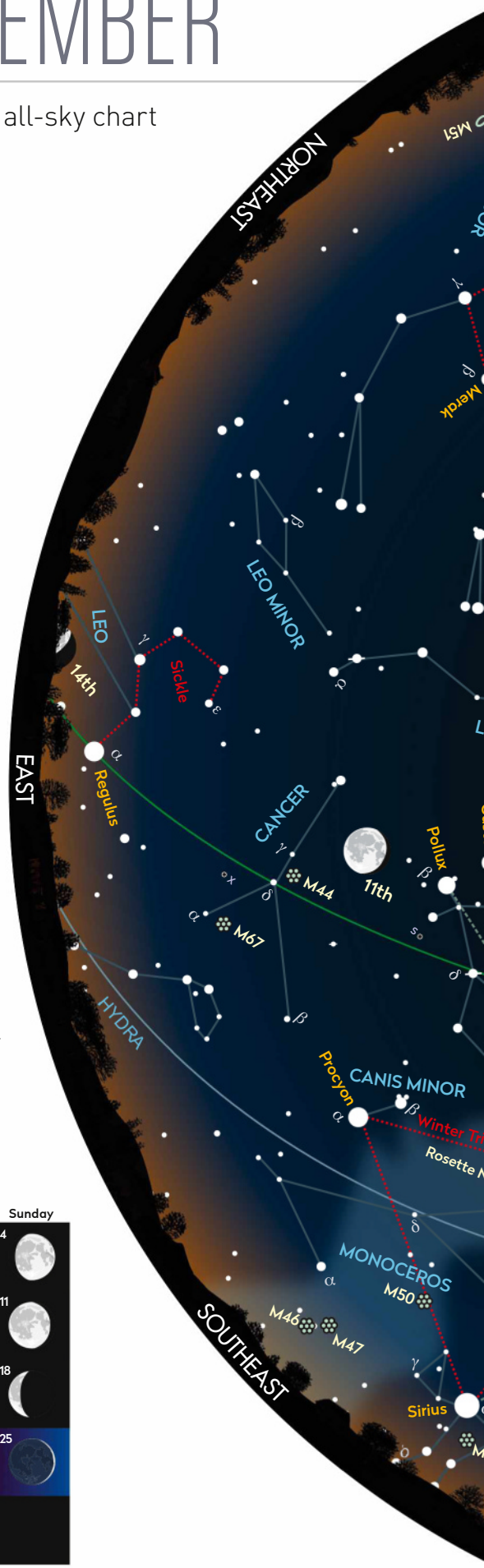
Moonrise times

1 Dec 2022, 13:44 UT	17 Dec 2022, 00:31 UT
5 Dec 2022, 14:28 UT	21 Dec 2022, 06:07 UT
9 Dec 2022, 16:19 UT	25 Dec 2022, 10:51 UT
13 Dec 2022, 20:47 UT	29 Dec 2022, 12:03 UT

*Times correct for the centre of the UK

Lunar phases in December





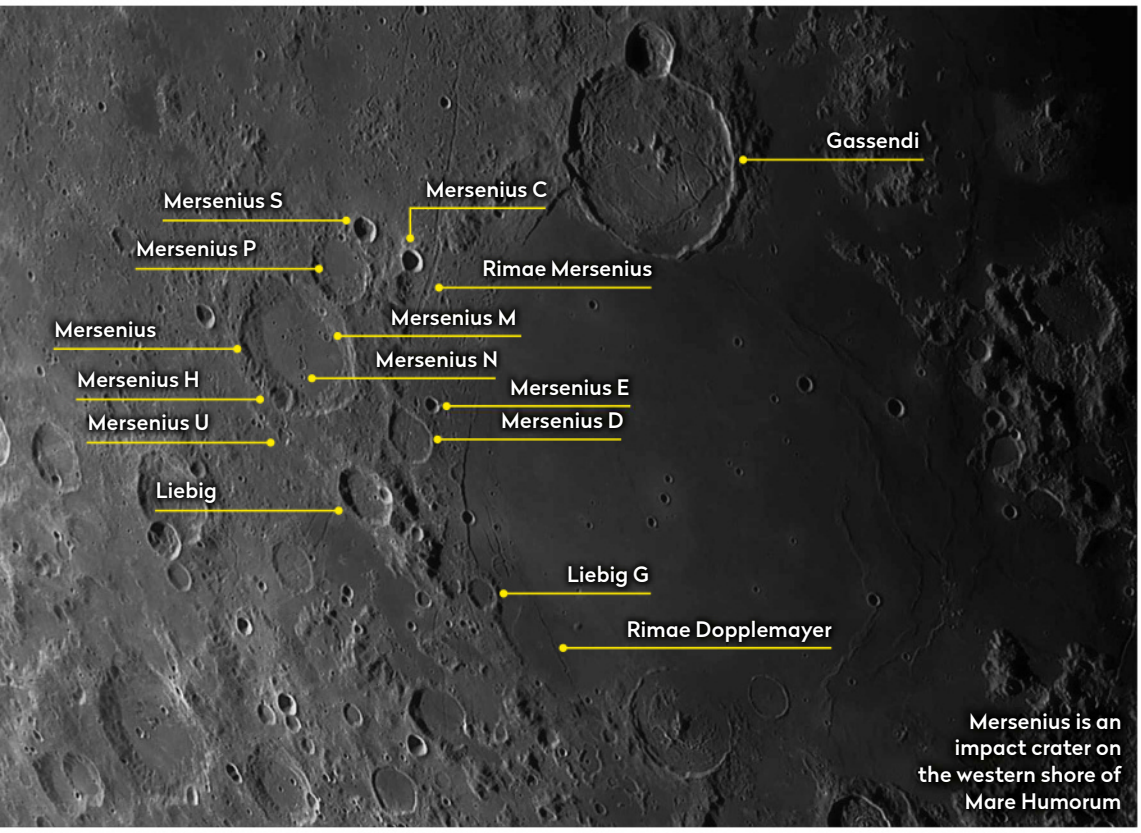
MORE **ONLINE**

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

MOONWATCH

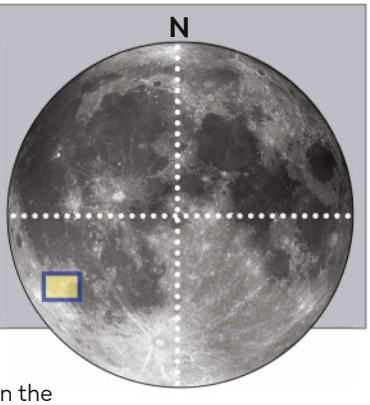
December's top lunar feature to observe



Mersenius is an impact crater on the western shore of Mare Humorum

Mersenius

Type: Crater
Size: 85km
Longitude/Latitude: 49.3° W, 21.5° S
Age: Around 3.9 billion years
Best time to see: Four days after first quarter (5 and 6 December) or three days after last quarter (19 December)
Minimum equipment: 50mm refractor



Mersenius is a fine lunar crater located on the western edge of **Mare Humorum**, the Sea of Moisture. With a diameter of 85km it is a large feature that blends into its surroundings rather well. Its rim is battered and irregular in shape. This is particularly evident around its north section, clockwise to the east, which is wide with a relatively gentle slope. Moving anti-clockwise to the west from north, it appears better-defined and initially steeper. The crater's depth is 2.3km, but the centre of the otherwise flat floor bulges upward by 450 metres. There is no indication of a central mountain complex, the flat floor being pockmarked by mostly tiny craterlets and, under high magnification with larger instruments, a number of fine cracks.

Of the inner craterlets, the largest is 5km **Mersenius M** which sits near the eastern rim.

PETE LAWRENCE X 3

Of the inner craterlets, the largest is 5km Mersenius M near the eastern rim

Towards the southwest rim lies **Mersenius N** which, at 3km across, is a good test for a large telescope. It sits near to 15km **Mersenius H**, a larger crater that interrupts the rim of Mersenius itself. If you have a larger scope like a reflector over 200mm, try to make out the form of **Mersenius U**, which 'hangs' south of H and looks like the outline of a drip of water.

Heading southeast from Mersenius is 34km **Mersenius D** which, thanks to a smaller crater interrupting the northmost section of its rim, also has a teardrop appearance. Mersenius D sits immediately on the edge of 380km-diameter **Mare Humorum** and is flanked by 36km **Liebig** to the southwest and 10km **Mersenius E** to the northeast. Mersenius E has a sharp rim leading down to a tiny, flat floor section. A small 2.4km craterlet sits perfectly on its eastern limb. With high-resolution imaging equipment you could try to image this crater to see whether you can pick up a dark band running from the 2.4km craterlet down to the 2km floor of Mersenius E.

Mare Humorum has many cracks along its border regions. One that begins just to the east of Mersenius, runs for 230km to the north, passing to the west of the impressive 111km **Gassendi** crater on the northern edge of the mare. The largest rille of **Rimae Mersenius** is around 2km wide for most of its length, widening to 3km near to its southern end.

The region to the northeast of Mersenius is dominated by 42km **Mersenius P** which, like its named parent, is also completely flat inside. Nearby are two sharp craters with small round floor sections: 16km **Mersenius S** touching the northeast rim of P, and 14km **Mersenius C** which lies to the east of S, near to where Rimae Mersenius passes.

As the morning terminator sweeps across Mare Humorum to reveal Mersenius, it's worth spending some time on the shores of the mare trying to trace the various cracks on Humorum's surface. In particular, look for the arrangement northeast of 20km **Liebig G**, part of the **Rimae Doppelmayer** complex.

COMETS AND ASTEROIDS

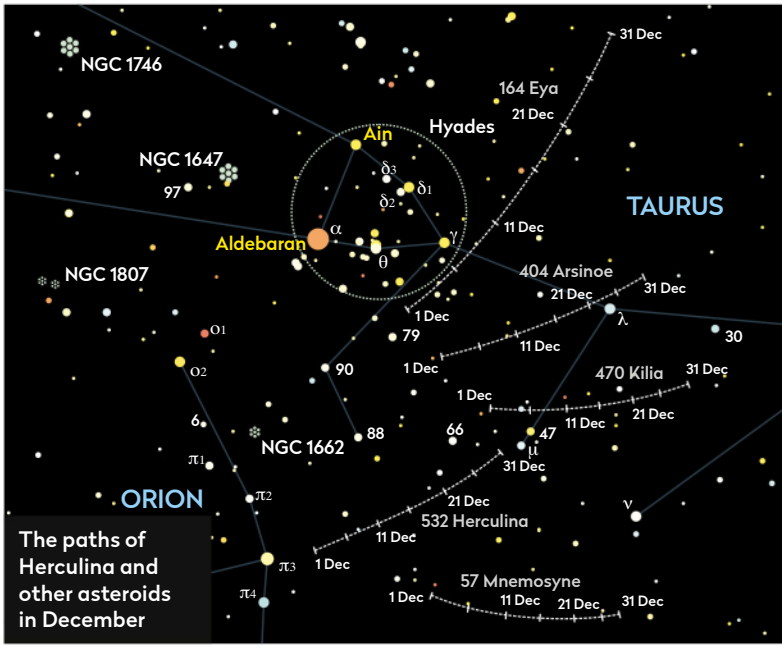
Asteroid Herculina should be an easy spot in Orion and Taurus this month

Asteroid 532 Herculina reaches opposition on 2 December when it will brighten to mag. +10.1 as it moves from Orion into Taurus, where it spends most of December. As the weeks pass, it only dims by 0.3, ending the month at mag. +10.4. The good news is that it is particularly easy to identify and gets to a good altitude under the darkness of a winter sky, giving you a great opportunity to track this relatively dim object over the month.

Herculina was discovered in April 1904 by Max Wolf at the Heidelberg-Königstuhl State Observatory. Wolf was a pioneer of astrophotography and had developed photographic methods to automate the discovery of asteroids. Wolf himself discovered an impressive 248 asteroids in his lifetime.

Herculina is a large main belt asteroid estimated to be 200km across. Its precise shape and size are still to be confirmed, but it is believed to be like a battered cube, a shape some have described as resembling a toaster! Its orbit takes it out as far as 3.26 AU and in as close as 2.29 AU from the Sun, taking 4.62 years to complete. At favourable oppositions, Herculina shines at mag. +8.8, while at unfavourable ones, it dims down to mag. +12.0.

During December, Herculina can be found travelling between mag. +3.2 Pi[3] (π^3) Orionis in a gentle arc taking it west-northwest towards mag. +4.3 Mu (μ) Tauri. This path is less than 10° to the south of the V-shaped Hyades open cluster, presenting an opportunity to record the cluster and asteroid in a single photograph. Overlaying and 'blinking' a series of photographs will show the movement of 532 Herculina, as well as several other asteroids in the vicinity.



The paths of Herculina and other asteroids in December

STAR OF THE MONTH

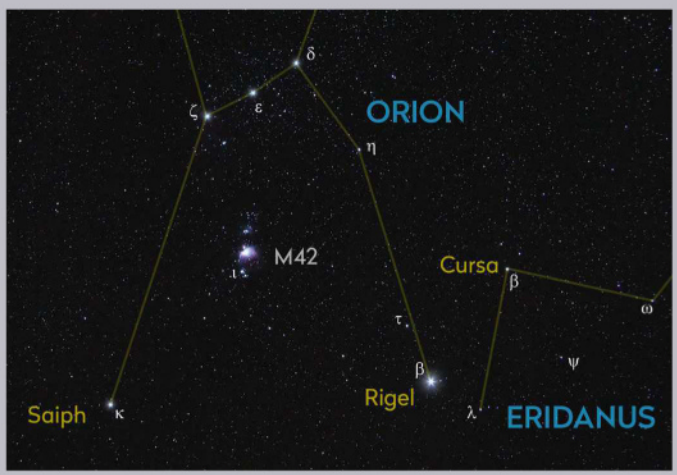
At the river's end, Cursa, 2nd-brightest star in Eridanus

The constellation Eridanus, the River is very long. It starts near the foot of Orion, which is marked by blue supergiant Rigel (Beta (β) Orionis). The River starts at the group of stars mag. +3.6 Tau (τ) Orionis and mag. +4.3 Lambda (λ), mag. +4.8 Psi (ψ) and +2.8 Beta (β) Eridani, the latter known as Cursa. This group was known in Arabic as 'the chair (or footstool) of the Central One'. This is one of two footstools used by Orion, the other known as 'the hindmost chair of Jawzā', formed from stars in Lepus further to the south.

Back to the foremost footstool, and Cursa is clearly the brightest of the three Eridani stars. Located 3.5° northwest of Rigel, it stands out well in the sparse area southwest of Orion. The river meanders back and forth as it heads south. Eridanus's brightest star is mag. +0.4 Achernar (Alpha (α) Eridani), a name that means 'the end of the river'. This is too far south to be seen from the UK.

Cursa is a giant of spectral class A3 III. It's a rapid rotator too, with a projected rotational velocity of 196km/s (our Sun's rotation is 2km/s at its equator). The star has twice the mass of the Sun and shines with a luminosity 25 times larger. It is interesting that its motion through space suggests it belongs to the Ursa Major Moving Group, although physical property mismatches suggest it may just be an interloper.

▼ **Bright star Cursa is easily located, near the foot of Orion, the Hunter**

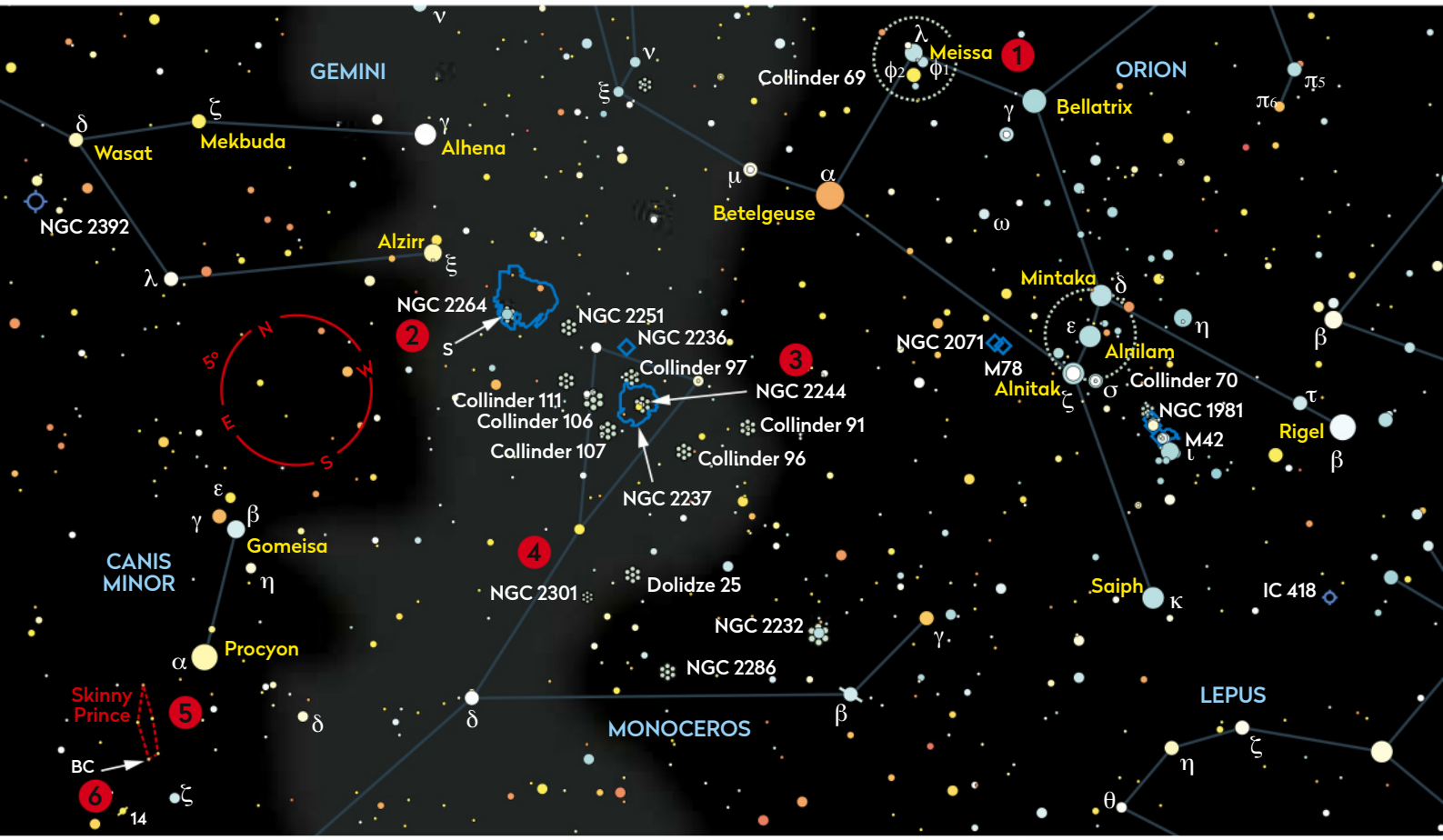


Cursa has a rare stellar property in that it can exhibit bright flash events. In 1985 it brightened by a factor of 15 for a period of a couple of hours.

BINOCULAR TOUR

With Steve Tonkin

This month, we turn at a T-junction, pop into a house and admire the Christmas Tree



PETE LAWRENCE X 3

1. The Meissa Cluster

10x 50 When you look at Orion's 'head' through binoculars, you can immediately see why it looks distinctly fuzzy to the naked eye: it is a small cluster of stars. The dozen or so stars that you can resolve are dominated by the brilliant white mag. +3.5 Meissa (Lambda (λ) Orionis). The other two bright stars in the field of view are the sapphire-blue mag. +4.4 Phi[1] (φ1) Orionis and deep-yellow mag. +4.1 Phi[2] (φ2) Orionis. ☐ **SEEN IT**

2. The Christmas Tree Cluster

10x 50 The seasonally appropriate NGC 2264, the Christmas Tree Cluster, lies 6.5° south of Alhena (Gamma (γ) Geminorum), surrounding the slightly variable (mag. +4.6 to +4.7) distinctly blue star, S Monocerotis. S Mon is in the base of the narrow wedge of stars that form the inverted tree. There is a lot of interstellar dust in this region of the Milky Way, which is why there seems to be a paucity of faint stars. ☐ **SEEN IT**

3. NGC 2244

10x 50 About 2° east of mag. +4.4 Epsilon (ε) Monocerotis, there is a narrow rectangular group of stars a bit less than 0.5° long that is quite difficult to identify as a distinct cluster; it looks more like a slightly denser accumulation in the Milky Way. You should see about a dozen stars but, unless you have exceptional skies, don't expect to detect the surrounding glow of the Rosette Nebula that gave birth to them. ☐ **SEEN IT**

4. NGC 2301

15x 70 Our next cluster can be difficult to find, but it's worth the effort. You'll find it 5° west of mag. +4.1 Delta (δ) Monocerotis. It has been named 'Hagrid's Dragon' but it looks more like a little T-junction of 8th- and 9th-magnitude stars. It covers a little more than 10 arcminutes and appears as a few brighter stars against the slightly mottled glow of the 40 or so fainter suns that comprise the cluster. ☐ **SEEN IT**

5. The Skinny Prince

10x 50 About 2.5° east of mag. +0.5 Procyon (Alpha (α) Canis Minoris), find five 6th(ish)-magnitude stars in the shape of a narrow 'house', reminiscent of Cepheus. There are some lovely colours here, especially the ruddy semi-regular variable BC CMi (mag. +6.14 to +6.42, with a period of about 35 days). It's worth scanning the wider area to see what other colourful star fields you can find. ☐ **SEEN IT**

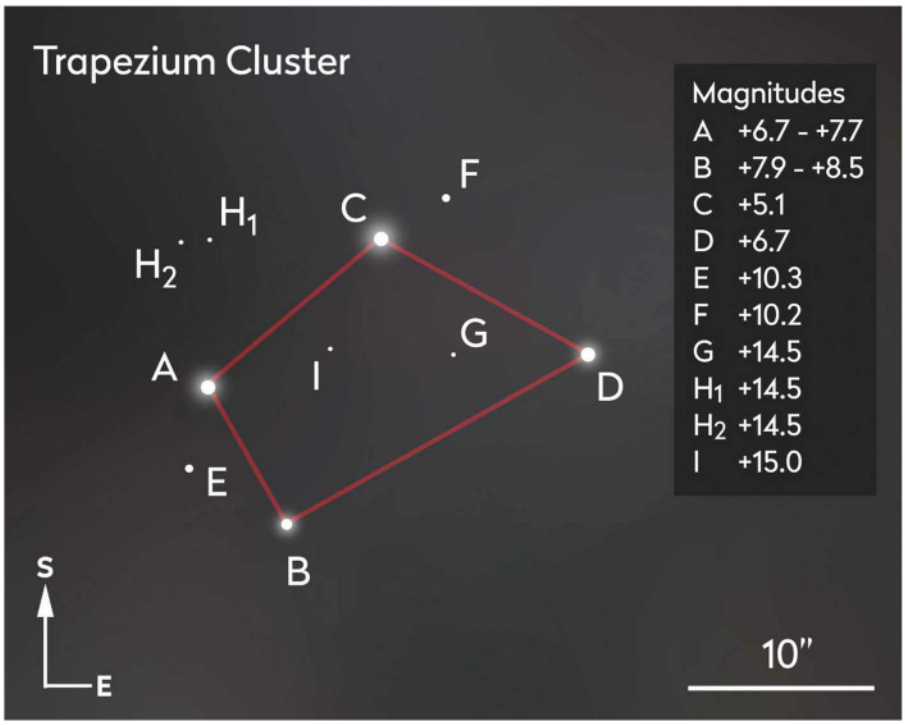
6. 14 CMi

15x 70 Your scan around the Skinny Prince probably included mag. +5.3 14 Canis Minoris. This deserves a closer look, ideally using larger binoculars. It is a triple star, with two much fainter companions. The brighter one (mag. +9.4) lies 102 arcseconds to the east; the other (mag. +9.8) is 137 arcseconds to the southeast of 14 CMi. Can you detect any colour difference between the two fainter stars? ☐ **SEEN IT**

☑ Tick the box when you've seen each one

THE SKY GUIDE CHALLENGE

Can you resolve not just the Trapezium Cluster but its fainter hangers-on?



▲ **Our challenge stars range from easy to extremely difficult – how deep can you go?**

This month's challenge is to try to see some of the fainter members of the Trapezium Cluster, also known as Theta[1] (θ^1) Orionis, which lies at the heart of the widely observed and photographed Orion Nebula, M42. The nebula is easy to find, being located right in the middle of Orion's sword, a line of faint stars and deep-sky objects that hangs south of Orion's belt.

A small scope shows the four brightest stars that form the trapezium shape: A, B, C and D. Magnitude +5.0 Theta[2] Orionis sits 2.3 arcminutes to the southeast, still within the nebula boundary.

Splitting the four component stars requires a medium to high power, but isn't particularly difficult. The brightest of the stars, at magnitude +5.1, is Theta[1] C. Next brightest is mag. +6.7 Theta[1] D. Theta[1] A is variable, an eclipsing binary with a magnitude that ranges from +6.7 to +7.7 repeating over a period of 65.432 days. Theta[1] B is another eclipsing binary with a 6.471-day period and is the faintest of the four, dropping from mag. +7.9 to +8.5 when eclipsed. The letter ordering follows the convention of labelling west to east, although as we delve deeper, this guideline is broken.

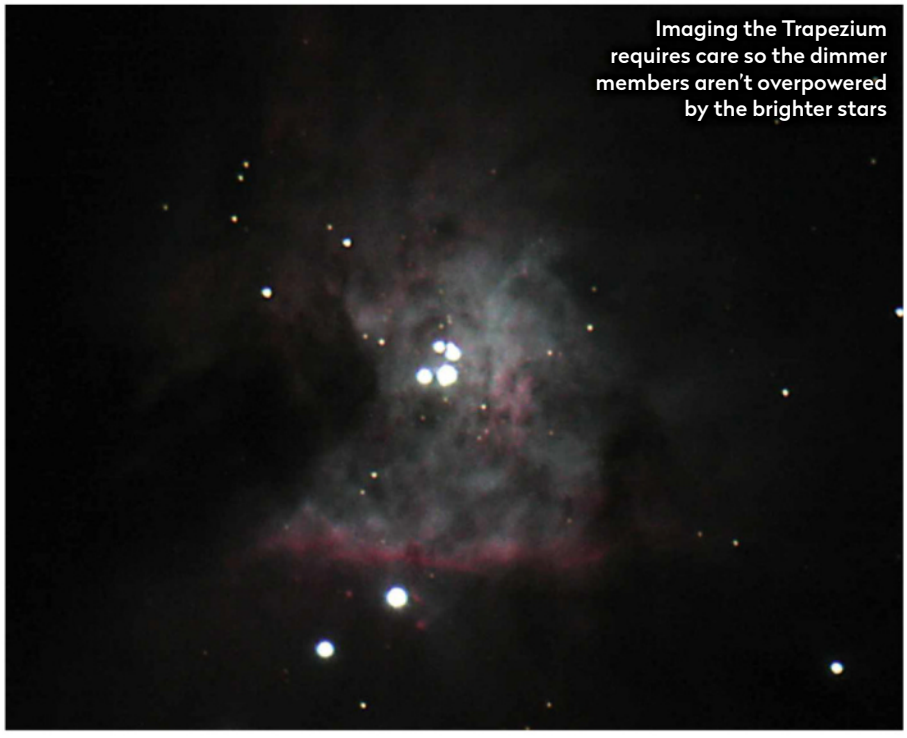
The main pattern has fainter cluster stars within and adjacent to it. The trapezium measures 19.2 arcseconds on its longest side (B–D) and just 8.7 arcseconds on its shortest (A–B). Acting as the corner anchors of the trapezium shape, the main stars and relatively small angular dimensions can make seeing the fainter marked members quite tricky.

In alphabetical order, mag. +10.3 E is located 4 arcseconds northwest of the mid-point between A and B. F shines at mag. +10.2 and is located 4 arcseconds southeast of C.

Stars G and H are quite dim and this makes them significantly harder to identify. Magnitude +14.5 G can be found within the trapezium itself, one-third of the way along the line from D to A. Its position makes it hard to image as unstable seeing bloats the brighter stars, swamping G in the process. G is a 'proplyd', a term describing an ionised protoplanetary disc – essentially a solar system in the process of formation.

The pair of stars labelled as H_1 and H_2 are easier because they sit outside the trapezium. They are faint though, both shining at magnitude +14.5. Locate them by drawing an imaginary line from E through A and extending it for twice the distance again.

The final challenge is a tough one. Magnitude +15.0 I sits within the trapezium slightly south of the two-thirds position from D to A. Like G, objects H_1, H_2 and I are also proplyds.



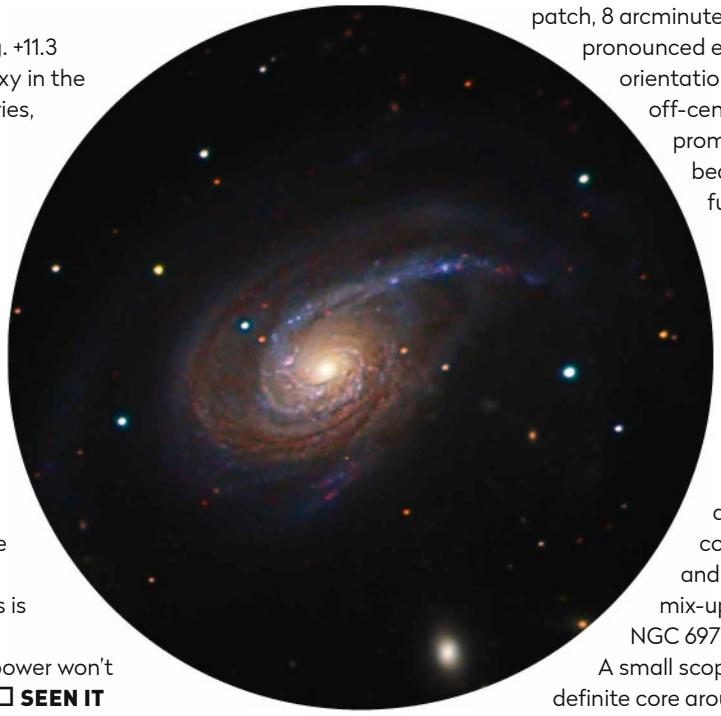
Imaging the Trapezium requires care so the dimmer members aren't overpowered by the brighter stars

DEEP-SKY TOUR

We explore the best celestial sights around Aries, Pisces and Triangulum

1 NGC 821

Our starting object is mag. +11.3 NGC 821, an elliptical galaxy in the extreme southwest corner of Aries, 12.5° south of mag. +2.0 Hamal (Alpha (α) Arietis). A mag. +9.2 foreground star lies a fraction to the west-northwest of the galaxy's centre. Even in a 250mm scope, NGC 821 is little more than a smudge, 1.4x0.6 arcminutes across and elongated from southwest–northeast. A 300mm scope doesn't pull a great deal more from this galaxy. Start off with medium magnification to reveal that the galaxy seems to concentrate towards a star-like nucleus. This is particularly evident at higher magnifications, but increased power won't do the outer halo any favours. ☐ **SEEN IT**



▲ **Unbarred spiral galaxy NGC 772 with its distinctive elongated arm is twice as big as our Galaxy**

2 NGC 772

We head north towards the three stars that form the most recognisable part of Aries to find the unbarred spiral galaxy NGC 772. This shines at mag. +11.1 and unlike NGC 821 is visible in smaller scopes. It lies 1.4° to the east of Mesarthim (Gamma (γ) Arietis) and shows as an oval glow with a defined core that brightens to a star-like nucleus through a 150mm scope, and appears distinctly mottled with larger apertures. A 300mm scope shows an object 3.5x1.5 arcminutes in size. The galaxy's seemingly diminutive appearance from Earth is misleading. Located 130 million lightyears from us, this object is estimated to be around twice the size of our own Milky Way Galaxy! ☐ **SEEN IT**

3 M74

Heading next door into Pisces, 2.4° west of the western Aries border we find face-on spiral M74. The guide point here is to imagine a line from Hamal to Sheratan (Beta (β) Arietis). Extend it almost twice that distance again to reach mag. +4.0 Eta (η) Piscium; M74 lies 1.3° to its east-northeast. A small instrument shows a slightly elongated patch of light 6 arcminutes across that gently brightens towards the centre. A 250mm scope reveals a larger patch, 8 arcminutes across with more pronounced elongation with an east–west orientation. The core appears slightly off-centre. A large aperture reveals a prominent granular centre and a beautifully mottled outer halo, full of faint detail. ☐ **SEEN IT**

4 NGC 697

We return to the Aries grouping of three main stars, Hamal, Sheratan and Mesarthim, for NGC 697. It's located 1.7° to the northwest of Sheratan, 0.3° to the northeast of the double star 1 Arietis, whose component magnitudes are +5.8 and +7.1. Presumably due to a mix-up somewhere down the line, NGC 697 is also known as NGC 674. A small scope shows an object with a definite core around 1 arcminute across, which grows only slightly through a 250mm scope, which also reveals an elongated core. A 300mm instrument shows a marginally larger galaxy of 2.0x1.0 arcminutes, elongated east–west. ☐ **SEEN IT**

5 Collinder 21

We head north out of Aries for the open cluster Collinder 21. It is located 4.6° to the north of NGC 697 and 0.6° north of mag. +6.9 HIP 8490 in Triangulum. At 9 arcminutes across and mag. +8.2, a small telescope won't have any trouble finding the stars that make up this tight group. Its brightest stars form a shape reminiscent of the semi-circular constellation Corona Borealis and range from eighth to 11th magnitude. Pretty though it appears, Collinder 21 isn't a true cluster at all but simply an an asterism, a line-of-sight arrangement of stars. About 15 stars populate the 'cluster' zone. ☐ **SEEN IT**

6 NGC 672/IC 1727

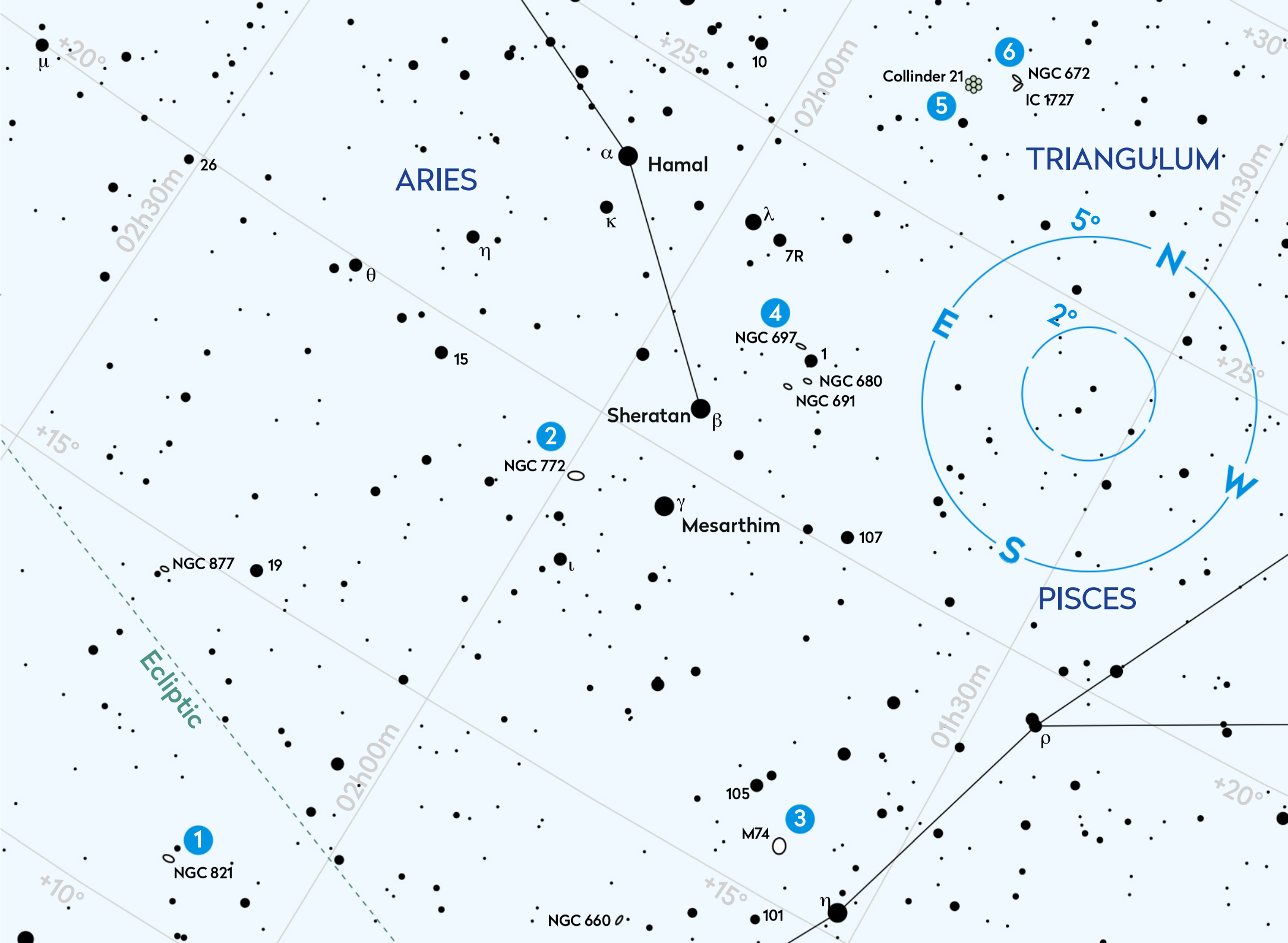
There are several galaxies surrounding Collinder 21, including spiral galaxy NGC 672 located 0.5° to the northwest. Shining at mag. +11.1, it is visible in small telescopes as a featureless elongated glow, brightening at its core. A 250mm scope shows an asymmetrical outer envelope measuring 4x1.5 arcminutes. Larger apertures reveal its core to be uneven in brightness and almost knotted in parts. NGC 672 forms an interacting pair with IC 1727, an irregular galaxy of similar apparent size immediately to its southwest. At mag. +11.6, IC 1727 is virtually invisible to smaller scopes. Larger instruments just show a glowing patch 3x1.5 arcminutes in size. ☐ **SEEN IT**

FRANZ KLAUSER/MANFRED WASSHUBER/CCDGUIDE.COM, CHART BY PETE LAWRENCE

This Deep-Sky Tour has been automated ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.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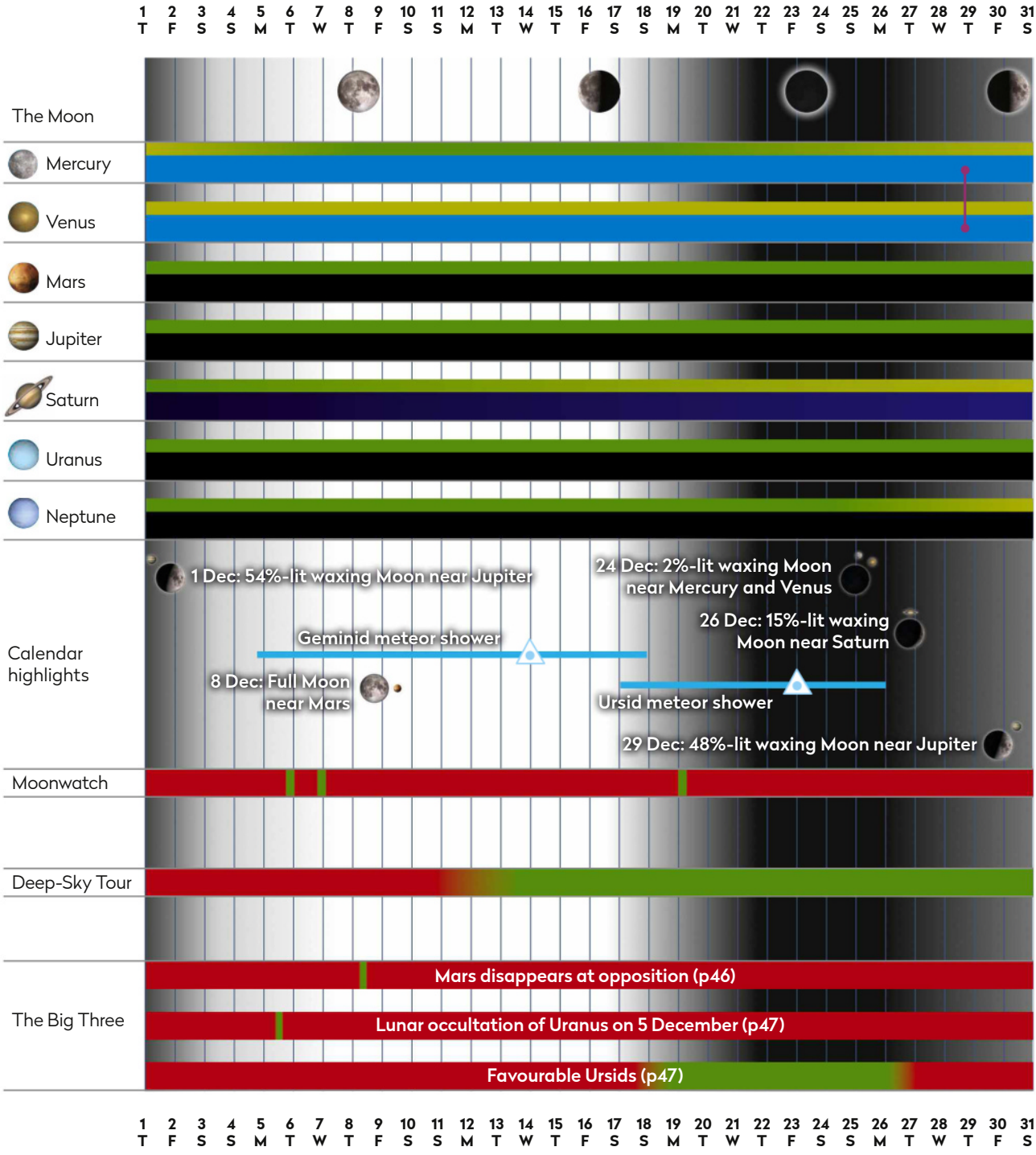
AT A GLANCE

How the Sky Guide events will appear in December



KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

- IC — Inferior conjunction (Mercury & Venus only)
- SC — Superior conjunction
- OP — Planet at opposition
- Meteor radiant peak
- Planets in conjunction

- Full Moon
- First quarter
- Last quarter
- New Moon

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How to deflect an ASTEROID

An epic trial run of a plan that may one day save Earth took place in September

Crash test dummy: DART closes in on small asteroid Dimorphos

NASA's Double Asteroid Redirection Test (DART) launched on 24 November 2021, heading towards the Didymos system – a large asteroid orbited by a smaller 'moon', Dimorphos. It arrived at the system on 26 September 2022 and at 11:14pm GMT that day crashed into Dimorphos's surface. The collision wasn't an accident but the mission's goal: NASA was attempting to deflect the small asteroid's orbit in a rehearsal for a future mission that could one day deflect an asteroid on a collision course with Earth, should one ever be found.

ILLUSTRATION

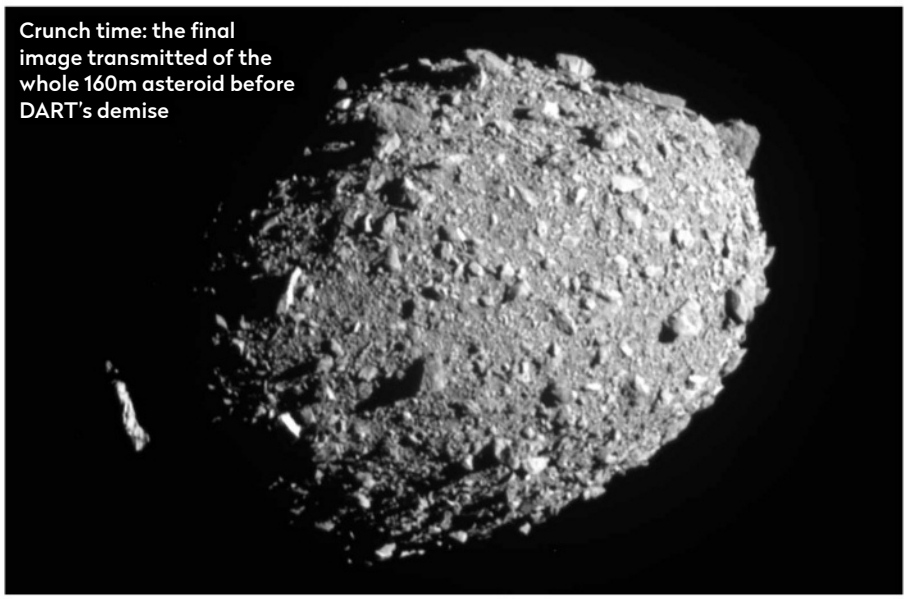
DART hits the bullseye

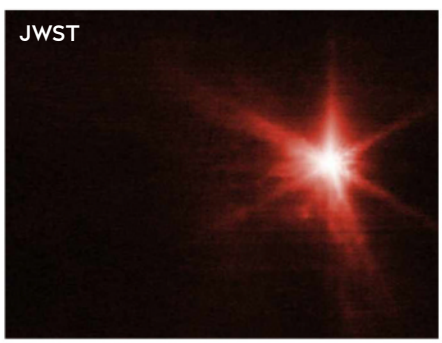
As DART closed in on Dimorphos at 22,530km/h, it livestreamed its navigation camera's view back to Earth. Its last image, taken just six kilometres from the surface, cut out half way through transmitting as the spacecraft was destroyed.

Three minutes later, the Light Italian CubeSat for Imaging of Asteroids (LICIACube) – which had separated from DART 15 days earlier – flew past to photograph the impressive dust cloud raised by the impact. Meanwhile, dozens of amateur and professional telescopes on Earth were watching closely. The asteroid, 9.6 million kilometres away, was just a dot, but they clearly saw a flare in brightness during impact, followed by trails of ejecta spreading away.

Astronomers then set about remeasuring Dimorphos's orbit time to see if its speed had changed. The goal was to shorten the orbit by one percent – about 10 minutes – though anything over 73 seconds would be a success. Within weeks Dimorphos's new provisional orbit time was announced: 11 hours and 23 minutes, a reduction of 32 minutes.

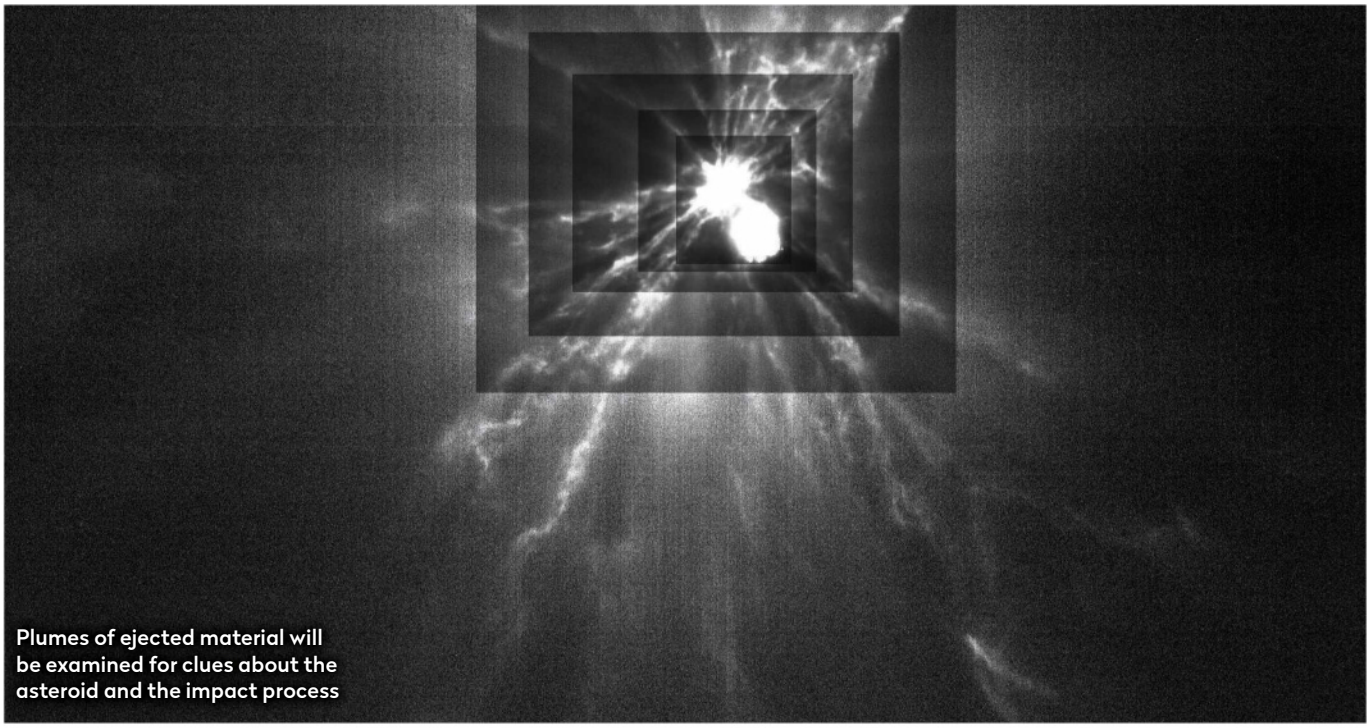
Crunch time: the final image transmitted of the whole 160m asteroid before DART's demise





▲ Both the James Webb and Hubble Space Telescopes captured the flare of the impact

NASA/JOHNS HOPKINS APL X 4, NASA/ESA/CSA/JIAN-YANG LI (PSI)/CRISTINA THOMAS (NORTHERN ARIZONA UNIVERSITY) IAN WONG (NASA-GSFC); IMAGE PROCESSING: JOSEPH DEPASQUALE (STSCI) ALYSSA PAGAN (STSCI). ASI/NASA/APL,



Plumes of ejected material will be examined for clues about the asteroid and the impact process

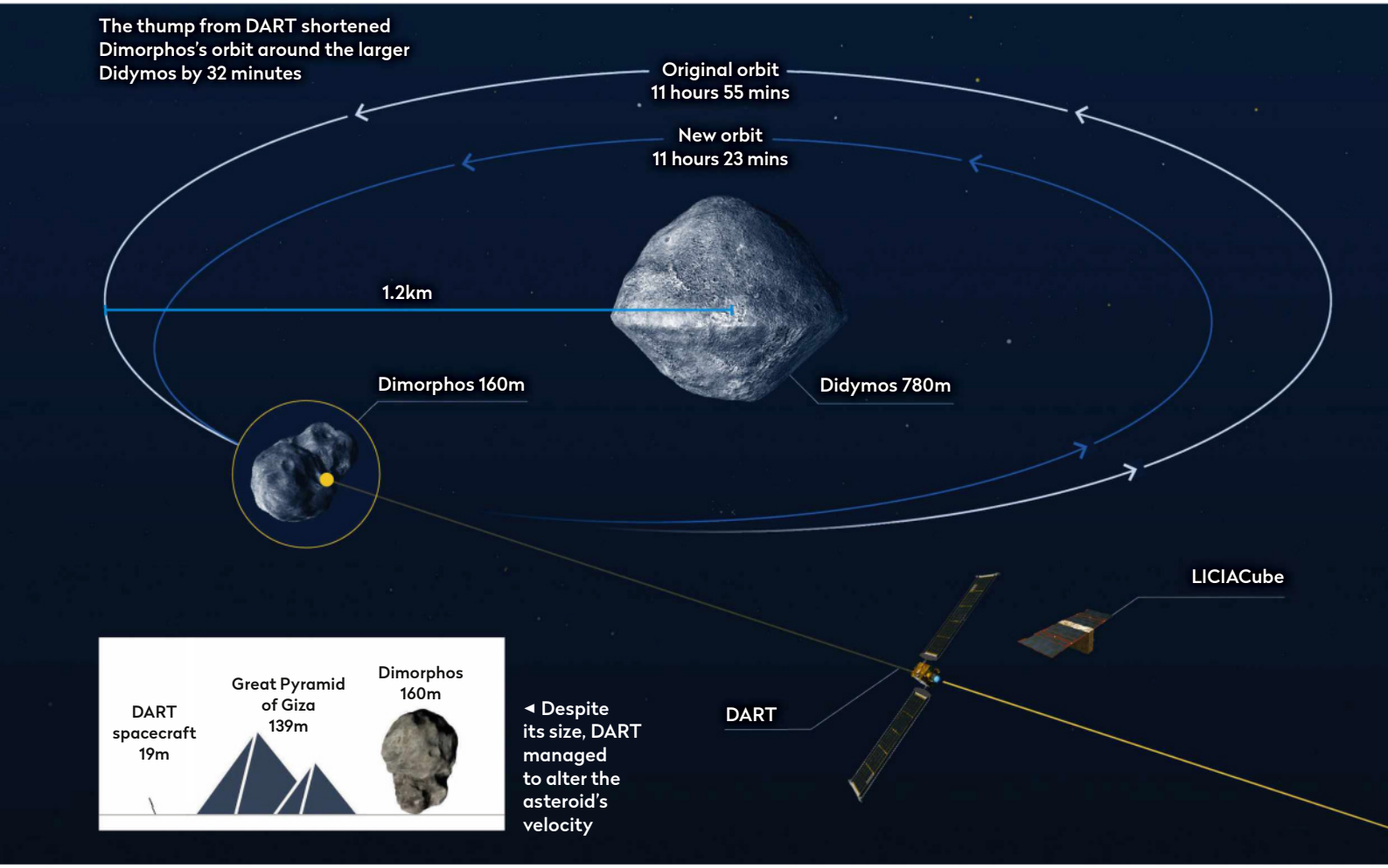
Understanding the impact's impact

The DART team now want to understand exactly how DART transferred its energy to Dimorphos. One particular area of interest is the dust cloud, as the recoil from its ejection could have amplified the impact.

First, they need to gauge Dimorphos's physical properties, such as its mass, composition and physical structure. The wealth of observations of the impact will help, but the best answers will come from the European Space Agency's Hera spacecraft. Launching in October 2024 and due to arrive in the system in 2026, it will observe both Didymos and Dimorphos for six months, mapping their surfaces and interiors to fully understand the effect of the impact.

Should a hazardous asteroid ever be discovered, this understanding will help predict the path of a deflected space rock and keep our planet safe.

The thump from DART shortened Dimorphos's orbit around the larger Didymos by 32 minutes



◄ Despite its size, DART managed to alter the asteroid's velocity

50 YEARS OF APOLLO

APOLLO 17

Apollo leaves its final footprints on the Moon in a mission marked by several remarkable firsts. Fifty years on, **Ezzy Pearson** looks back

By the time Apollo 17 launched in December 1972, the world had fallen out of love with the Moon. Apollo missions 18 through to 20 had already been cancelled due to waning public interest and constraints on US government budgets, but many questioned why Apollo 17 was still happening when every mission looked identical.

To the science community, though, each landing provided valuable new insights. Knowing this would be the last mission, NASA was determined that Apollo 17 would have something no landing mission had had before: a trained geologist in the form of Howard 'Jack' Schmitt as lunar module pilot. Mission commander Gene Cernan wasn't thrilled with the decision as Schmitt pushed out Joe Engle, whom both Cernan and Apollo 17 command module pilot Ronald Evans had served with on the Apollo 14 backup crew. Engle was also an experienced pilot and the landing site, Taurus–Littrow – a geologically interesting, but hazardous, mix of high- and lowlands – was the riskiest yet, so Cernan pushed for Engle. It was only when it was made clear Schmitt would fly with or without Cernan that he acquiesced. Luckily, the crew worked well together.

The launch was due on 6 December 1972 at 9:53pm local time, the programme's only night launch. Despite the late hour, 500,000 people came to watch as the clock ticked down from five minutes to one minute to 30 seconds... then stopped. There was a hold! Would the final Apollo mission be cancelled at the last moment? It transpired an oxygen tank had failed to pressurise. After manually setting it, the countdown recommenced.

MISSION BRIEF

Launch date: 7 December 1972

Launch location: Launch Complex 39A

Landing location: Taurus–Littrow

Time on surface: 74 hours, 59 minutes, 39 seconds

Distance covered by lunar rover: 35.7km

Duration: 12 days, 13 hours, 51 minutes, 59 seconds

Return date: 19 December 1972

Main goals: Collect highland material; investigate past volcanic activity

Achievements: First mission launched at night, first professional geologist on the Moon, furthest travelled from lunar module, most distance covered overall, most lunar material collected, proof of volcanism found, taking the Blue Marble photo

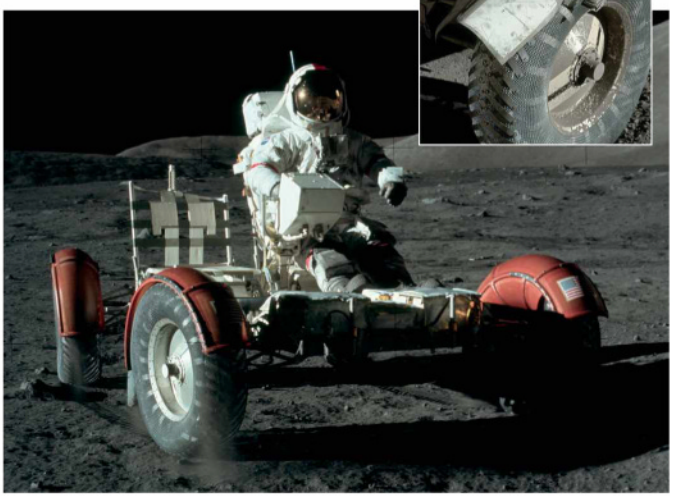
Lunar module name: Challenger

Command module name: America

NASA X 9

A visit to Tracy's Rock, named after Commander Gene Cernan's daughter, was one of the mission's many highlights

▲ Apollo 17 was the first-ever night launch of the Saturn V. Minor technical issues delayed the takeoff by two hours and 40 minutes



▲ Cernan test drives the lunar rover. A rear fender later required a makeshift repair (inset) after Cernan broke it during the first EVA

"As we leave the Moon at Taurus–Littrow, we leave as we came and, God willing, as we shall return, with peace and hope for all mankind. Godspeed the crew of Apollo 17"
– Gene Cernan

Ezzy Pearson is *BBC Sky at Night Magazine*'s features editor

At 12:33am EST on 7 December 1972, the final Saturn V launch rose into the air, golden flames blossoming behind it, brilliant as the Sun against the midnight blackness.

A crew in high spirits

The crew arrived in lunar orbit three days later, with Cernan and Schmitt departing for the surface on 11 December. Despite the dangerous terrain, Cernan guided the lunar module (LM) to a textbook landing and just four hours later the first extravehicular activity (EVA) began.

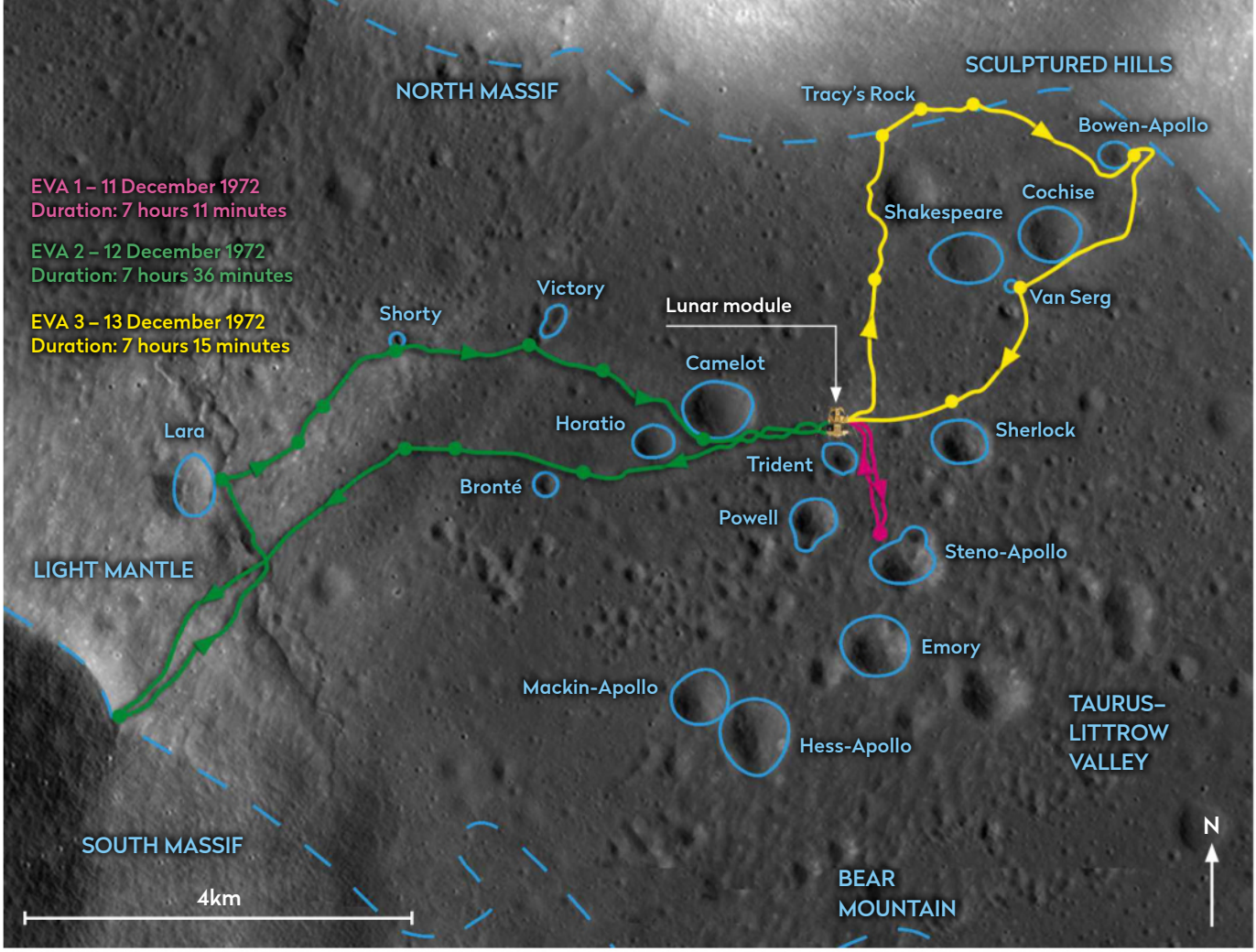
"As I step off at the surface of Taurus–Littrow, we'd like to dedicate the first step of Apollo 17 to all those who made it possible," said Cernan as he ventured onto the Moon. He followed this up by excitedly exclaiming, "Oh, my golly! Unbelievable!", dispelling any notion that the last Apollo mission would be a melancholy affair.

Once Schmitt joined him, they began deploying the lunar rover and surface experiments. Keenly aware he could be the only geologist to conduct a field expedition on the Moon for a long time, Schmitt raced through his tasks – perhaps a little bit too briskly, as mission control, reading his suit's temperature sensor, informed him "your exuberance is showing" and that he should calm down.

"Exuberance!" the geologist shot back, "I've never been calmer in my life," before bounding over to nearby Steno crater, singing, "I was strolling on the Moon one day, in the merry, merry month of... December."

After EVA 1, they returned to the LM to rest. The next day began with a spot of hasty repair work as Cernan had broken the rover's fender the previous day. Dust sprayed up by the wheels covered everything, causing problems with overheating. They had attempted a fix it with duct tape, but the dust and thick gloves made it impossible. Overnight, engineers back on Earth designed a makeshift fender using an old map and more duct tape, while Apollo 16 commander John Young donned a spacesuit to practice attaching it. He talked the moonwalkers through the repair, allowing EVA 2 to begin.

The pair journeyed 7.6km – the furthest any human has ventured from a pressurised environment – to Nansen crater, which was next to a compact group of mountains called a massif. Cernan found the best way to handle the sloping terrain was to "cover ground like a kangaroo", hopping on two legs. Schmitt wasn't quite as graceful, though. When he fell over near the next station at Lara crater, mission control joked, "The switchboard here... has been lit up by calls from the Houston Ballet Foundation ▸



▸ requesting your services for next season". They renamed the area 'Ballet crater'.

Any embarrassment Schmitt felt vanished at their next stop, Shorty crater. Schmitt was clearing away the top layer of dust with his foot to expose the material underneath when he saw something unexpected on the usually monotone Moon.

"Oh hey! There is orange soil!" he exclaimed.

One of the main reasons for coming to Taurus–Littrow was to look for evidence of past volcanic activity. The orange colour could be due to oxidisation, a strong indicator of volcanism. It later turned out the orange was caused by glass beads created by a type of volcano known as a fire fountain.

The pair spent as long as they could gathering samples, but they were coming up against their 'walk back limit', when they wouldn't have enough oxygen to return to the LM on foot in an emergency. They had to end the EVA. Clocking in at seven hours and 36 minutes and having traversed 20.4km, it was the longest moonwalk of the programme and the pair retired for a well-earned night's sleep.

The view from above

While the moonwalkers exerted themselves on the surface, Evans wasn't floating idle in the orbiting command module. He had his own programme, taking photos of the surface and using a new radar sounding device to image up to a kilometre beneath the lunar surface, as well as measuring temperature changes caused by the Moon going from day to night. He even watched the sunrise, sketching the solar corona as it peeked out over the horizon ahead of the Sun's disc.

Back on the surface, Schmitt and Cernan began their final EVA, exploring North Massif. Near the first stop, they found a huge boulder split in two, calling it Tracy's Rock after Cernan's daughter. A clear track extended up the slope where it had rolled down from higher up, giving them an easy way to collect a highland sample without the long uphill trek to get it.

Before long, it was time to return to the LM to load up their haul of 741 samples, weighing in at 110.5kg

▲ Record-breakers: the EVAs were the longest ever (22 hours and four minutes total) and covered the greatest distance ever travelled from a spacecraft (7.6km)

Meet the astronauts

Commander: Eugene 'Gene' Cernan
Born on 14 March 1934, Cernan served as a fighter pilot in the Navy. He flew on Gemini 9 and had previously visited the Moon with Apollo 10 before being made commander of Apollo 17. He left NASA in 1976 to work in private business, but continued to commentate on space exploration. He died on 16 January 2017, aged 82.

Lunar module pilot: Harrison 'Jack' Schmitt
The only Apollo astronaut never to have served in the US military, Schmitt was born on 3 July 1935. Shortly after achieving his PhD in geology from Harvard University in 1965, he joined NASA and helped to train many other moonwalkers in geology field work. After Apollo 17, he took up politics, serving as a US senator.

Command module pilot: Ronald Evans
Born on 10 November 1933, Evans was a highly experienced Navy pilot having logged over 5,500 hours of flight time. After Apollo 17, his only spaceflight, Evans stayed at NASA to work on the Space Shuttle. He left in 1977, later working for Sperry Flight Systems who built components for the Shuttle. He died on 7 April 1990.

NASA X 8, ILLUSTRATION BY PAUL WOOTTON (BASED ON NASA DATA)

MISSION TIMELINE

7 Dec 02:53
Launch held at T-30 seconds due to a pressurisation issue with an oxygen tank

7 Dec 05:33
Mission launches

7 Dec 08:51
Translunar injection propels Apollo 17 towards the Moon

10 Dec 19:53
Crew arrive in lunar orbit

11 Dec 17:20
Lunar module separates from command module and descends towards surface

11 Dec 19:54
Lunar module touches down on lunar surface

11 Dec 23:54 EVA 1 begins, lasting 7 hours, 11 minutes, 53 seconds

12 Dec 23:28 EVA 2 begins, lasting 7 hours, 36 minutes and 56 seconds

13 Dec 22:25 EVA 3 begins, lasting 7 hours, 15 minutes, 8 seconds

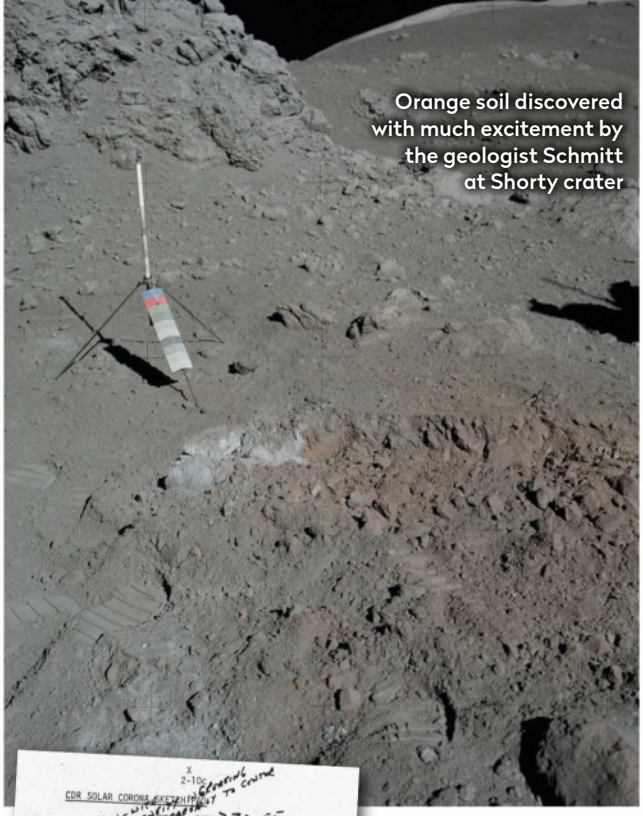
14 Dec 22:54
Lunar module relaunches

15 Dec 01:10
Lunar module redocks with command module, reuniting the crew

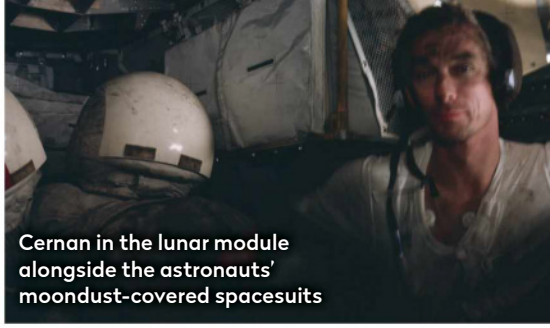
16 Dec 23:35
Trans-Earth injection propels spacecraft towards home

19 Dec 19:24
Splashdown

*All times are UT



Orange soil discovered with much excitement by the geologist Schmitt at Shorty crater



Cernan in the lunar module alongside the astronauts' moondust-covered spacesuits

Schmitt prepares the rover for its final excursion

▲ Sketches by Ronald Evans of the solar corona over the lunar horizon

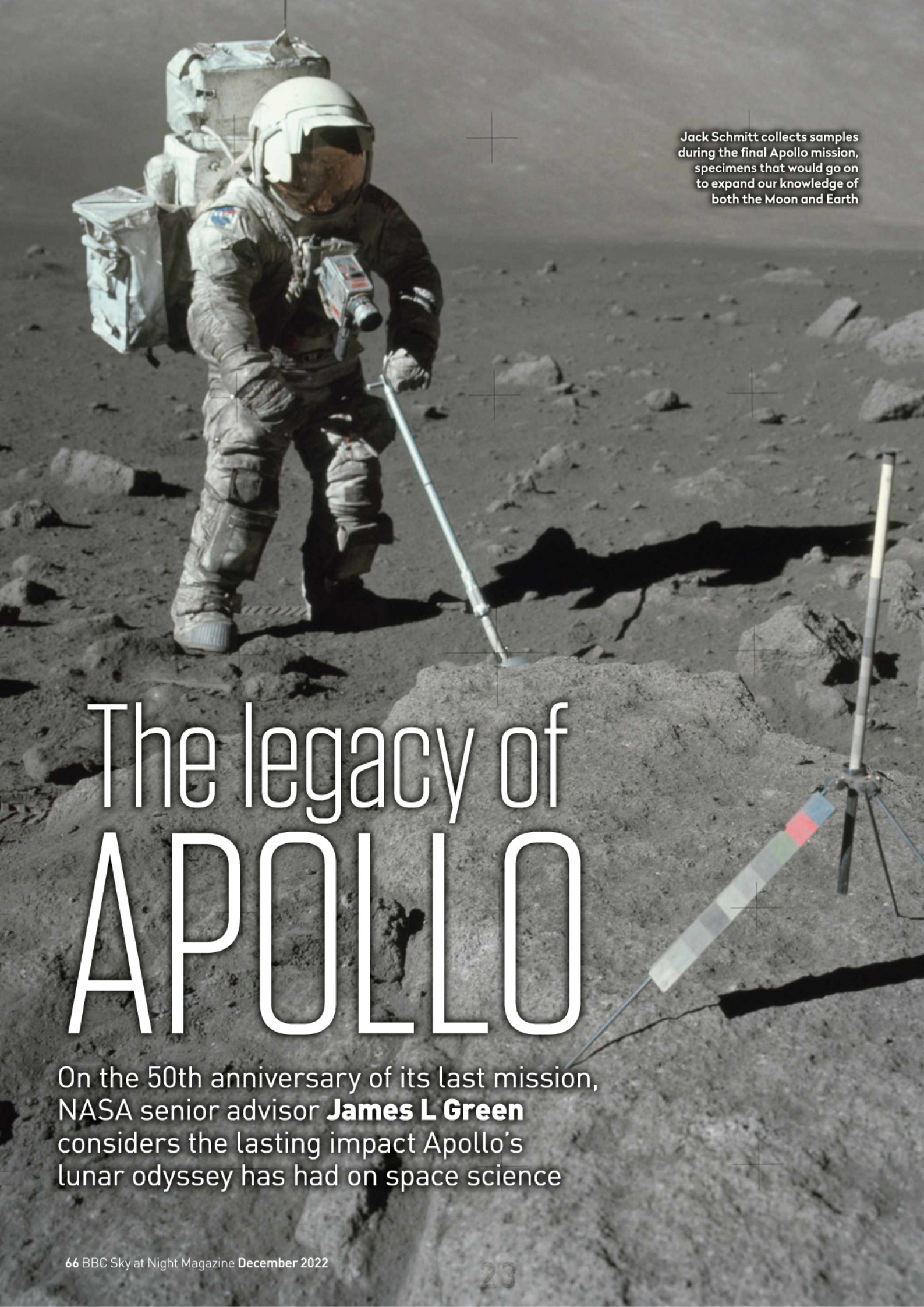
► This incredible shot of Earth's full disc became known as the Blue Marble and remains an iconic image of the Apollo era

– the largest of any Apollo mission – and close out the mission. Schmitt disposed of his geological hammer according to the old geologist tradition of hurling it into the distance before returning to the lunar module, leaving Cernan as the last human to walk the lunar surface.

"As we leave the Moon at Taurus–Littrow, we leave as we came and, God willing, as we shall return, with peace and hope for all mankind. Godspeed the crew of Apollo 17."

The next day the lunar module rose from the surface into the dark, reuniting with Evans a few hours later. On 16 December, the crew took their last look at the Moon's surface and fired the engines towards home. Breaking the journey only for Evans to perform a 65-minute EVA to retrieve film casettes, they splashed down three days later, concluding one of the most audacious endeavours in human history.

Apollo 17's trove of samples has been analysed in laboratories, fuelling lunar science for half a century – one was even kept in cold storage for 50 years and only thawed out this spring. But perhaps the most well-known legacy of Apollo 17 was a single image, taken at the start of the mission. While flying away from home, one of the astronauts captured a perfect shot of Earth, fragile and alone in the infinite cosmos. The Blue Marble photo is one of the most shared photographs of all time. Yet despite Cernan's plea that "we shall return", Apollo 17 was the last time someone was far enough away to capture planet Earth in a single frame... at least for now.



Jack Schmitt collects samples during the final Apollo mission, specimens that would go on to expand our knowledge of both the Moon and Earth

The legacy of APOLLO

On the 50th anniversary of its last mission, NASA senior advisor **James L Green** considers the lasting impact Apollo's lunar odyssey has had on space science

A Mars-sized object colliding with the proto-Earth is widely considered to be the most likely origin of the Moon

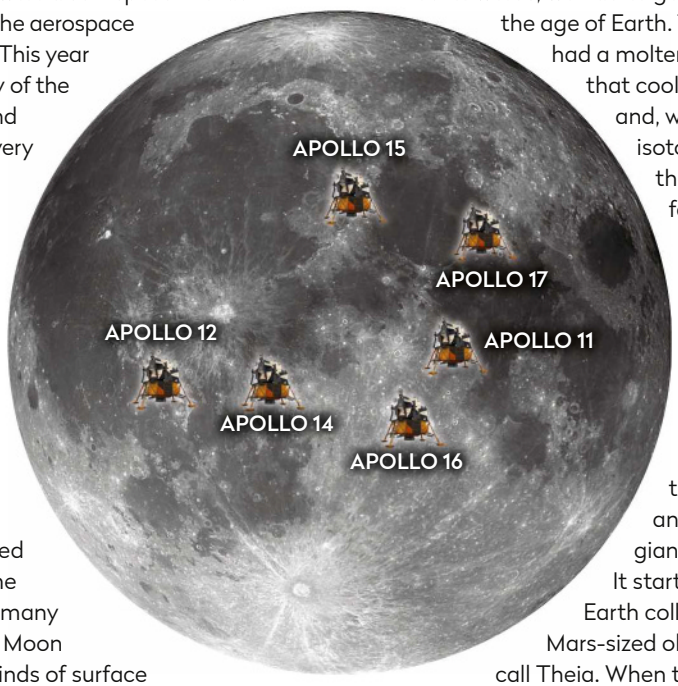
ILLUSTRATION

When we first landed on the Moon in 1969, fulfilling President Kennedy's 1962 declaration to put humans there by the end of the decade, I was in high school and over the next several years I followed each mission closely. Although I was already sure I wanted to be involved in space before the Apollo missions, so many of my fellow students were also inspired in that era to get involved in the aerospace industry in some way. This year is the 50th anniversary of the landing of Apollo 17 and although it seems so very long ago, the legacy of Apollo has made a significant difference in the exploration of space that followed.

When we look at where the Apollo landing sites are located (see right) we see that they are in the mid to low latitudes on the lunar near side and separated by great distances. The astronauts examined many different areas on the Moon and deployed many kinds of surface experiments, bringing back 382kg of lunar material. What we learned from all these efforts was truly astounding and took many decades for scientists to really appreciate and understand. In fact, even today we are still actively analysing lunar samples.

Determining the Moon's age

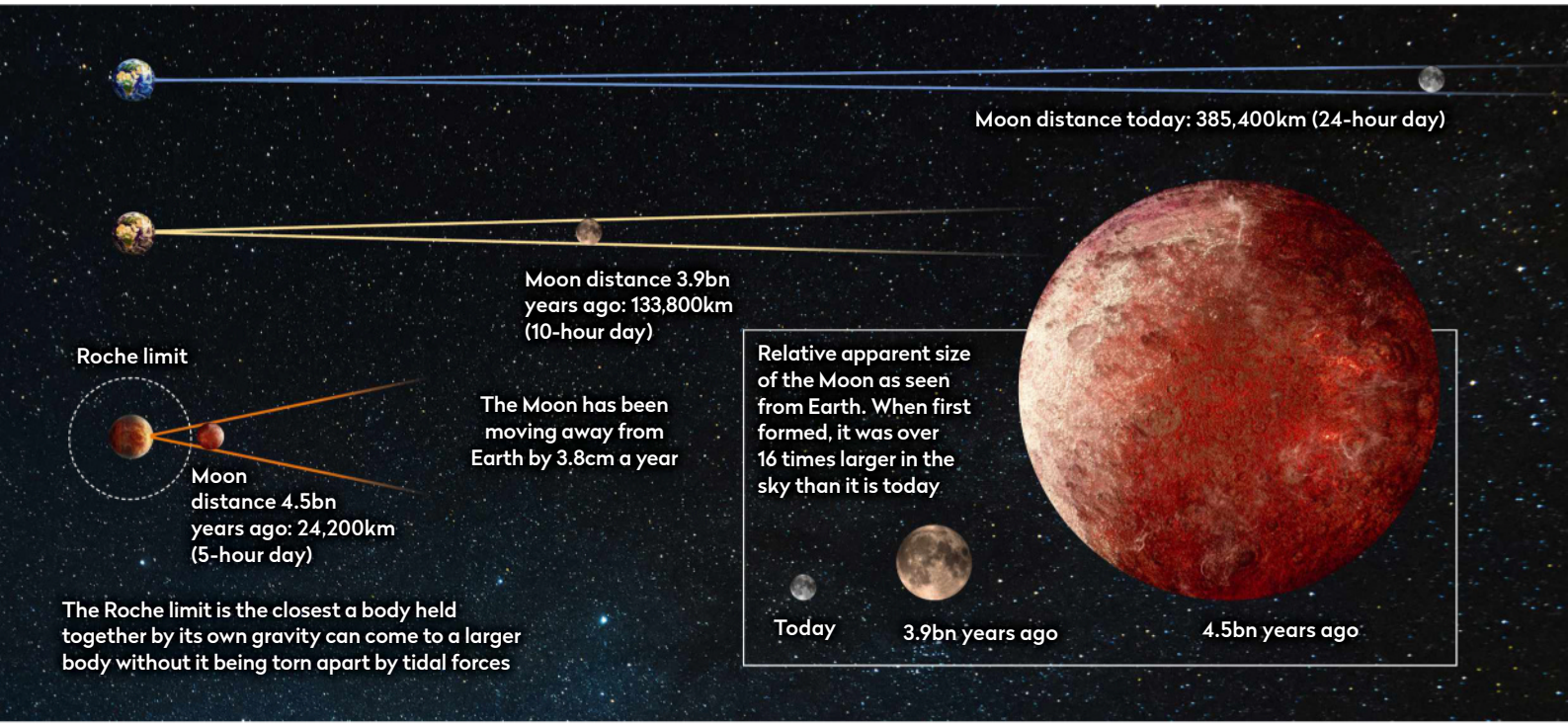
The Moon is old, around 4.5 billion years old in fact; much older than any rocks found on Earth today. We now know that, due to plate tectonics and erosion, Earth's early crust has completely disappeared. In other words, we had to go to the Moon to find the age of Earth. The young Moon had a molten magma ocean that cooled to form its crust and, when combined with isotopic analyses of the lunar rocks, these facts tell us that the Moon and Earth are virtually identical in composition. They were made at the same time and the same place in our Solar System.



▲ The six Apollo landing sites took in a wide variety of the Moon's landscapes

The top theory for the creation of Earth and the Moon is the giant impact hypothesis. It starts out with the proto-Earth colliding with another Mars-sized object, which scientists call Theia. When the dust settled on this planetary-scale collision, Theia was destroyed and the proto-Earth was reformed into a larger body, while ▸

NASA, PETE LAWRENCE, STOCKTREK IMAGES/ISTOCK/GETTY IMAGES



▲ The Moon's proximity to Earth early in its history would have had some interesting effects: there would have been larger tides, key perhaps to life's evolution, more lunar eclipses, and materials from large impacts on one body potentially landing on the other

▸ the ejected material formed a much smaller body. At that time the Moon was so close to Earth that it had a huge presence in the sky, being more than 16 times larger than we see it from Earth today.

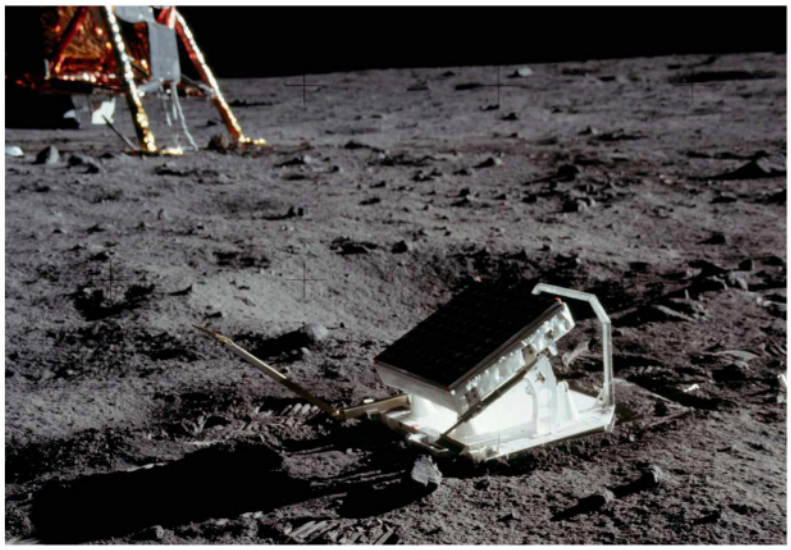
The Apollo astronauts left retroreflectors on the Moon, which scientists have targeted with lasers each year since 1969. From accurately measuring the light travel time from Earth to the Moon and back again, we find that the Moon is moving away from Earth by around 3.8cm each year. Over the last 4.5 billion years the Moon has moved from 24,200km to now lie 385,400km from Earth (see diagram above).

Telling the Solar System's story

The laboratory analysis of returned lunar rocks includes determining their mineralogy and age. The younger lunar rocks are from the darker mare regions and are basaltic or volcanic material from inside the Moon, filling large impact craters during a period from around 4.2 to 3.16 billion years ago, now referred to as the late heavy bombardment. For every one impact crater on the Moon, it is estimated that 20 meteorites hit Earth. Many will have burnt up in our atmosphere, but others would have made it to the ground. Over time, the dynamic climate and land motions of our planet have largely erased all traces of the initial impact craters, making the Moon the only witness to the early bombardment history of the inner Solar System.

Scientists now believe that the late heavy bombardment tells us of a dynamic early Solar System, where the giant planets changed their orbits due to gravitational resonances. Jupiter moved slightly inward, but Saturn, Uranus and Neptune all moved outward. Perhaps another giant planet was also ejected hundreds of astronomical units from the Sun, a distance so great that we can't see it with our modern telescopes. The motion of these giant planets changing their orbits around the Sun (a phenomenal concept I still have trouble picturing) gravitationally interacted with all the small-body debris of asteroids and comets, scattering them everywhere to produce this critical bombardment in the inner Solar System. The small bodies bombarding Earth had everything from organics to metals, reseeding the surface and perhaps bringing the right materials together for the spark of life to have started.

We now know that the Moon plays several critical roles in keeping the Earth uncommonly habitable. It causes lunar tides, stabilises Earth's spin axis and



▲ The Lunar Laser Ranging Experiment left behind by Apollo 11 and still used to measure the Moon's increasing distance

NASA X 2, GETTY, MARK GARLICK/ISTOCK/GETTY IMAGES


ILLUSTRATION

slows our planet's rotation rate, all believed to be important aspects for the development of complex life. This concept of giant planet migration has also informed our interpretation of other stellar planetary systems and exoplanets in many ways. Perhaps habitable exoplanets may also need an exomoon. It is thanks to the Apollo programme that we will never look at our Moon in the same way.

▲ **At 16 times larger than it appears today, the Moon would have been an incredible sight in the proto-Earth's night sky**

Driving spaceflight forward

Apollo's lunar samples and data have continued to raise significant interest from the world-wide science community. Indeed, it has helped establish a new scientific discipline by building a strong planetary science community, which at NASA is now driven to answer fundamental questions about the origin and evolution of our Solar System, and to determine if there is life beyond Earth. Human exploration of space is more politically driven.

Since NASA is an agency that falls under the Executive Branch in the United States, each new administration sets the strategic direction for human space exploration. After Apollo, the Nixon administration began to set the stage for NASA to develop the capability to explore how humans can live and work in low-Earth orbit. These activities included our first small space station called Skylab, the Space Shuttle, and then the International Space Station (ISS).

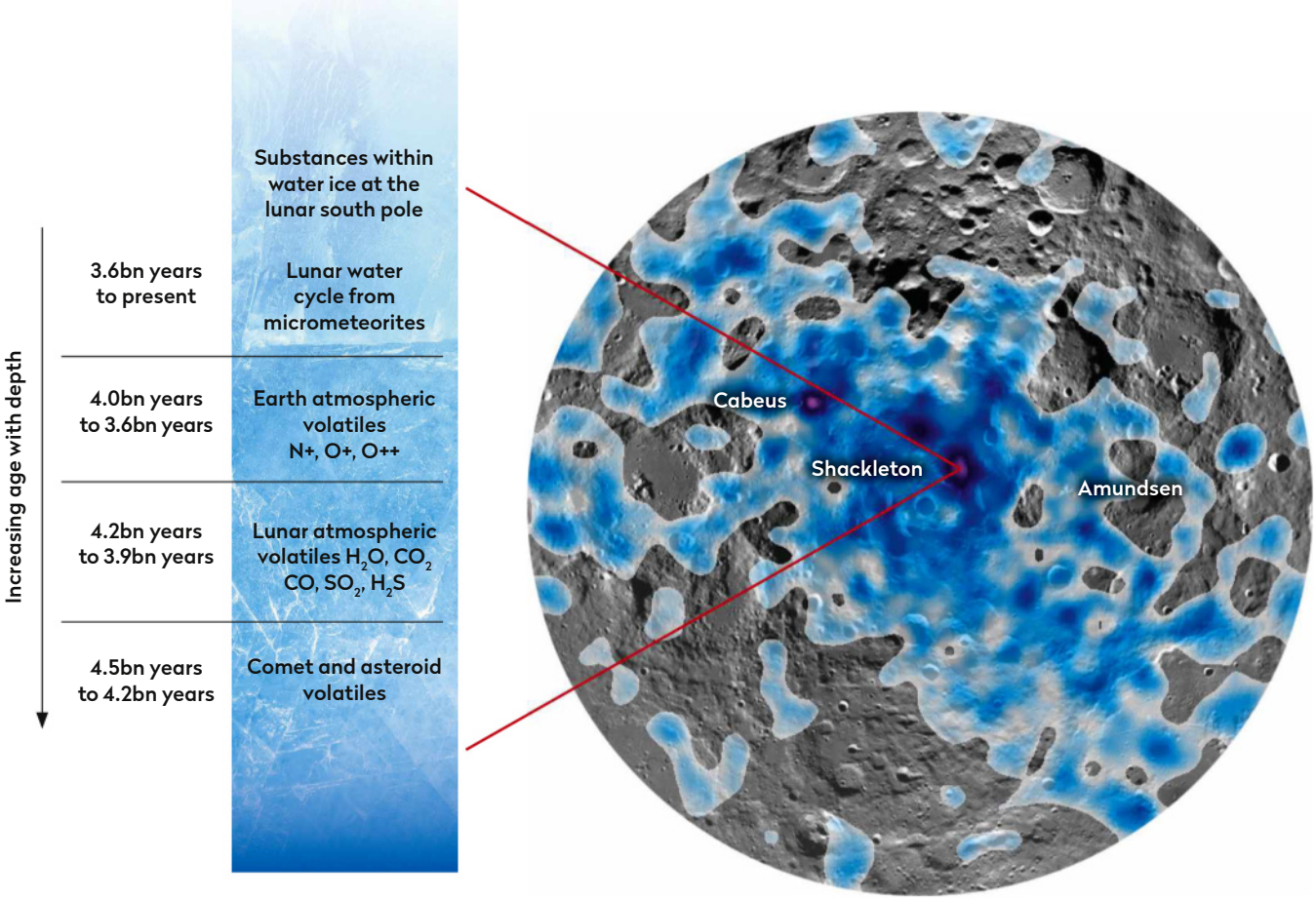
▲ **The ISS has become our place in space thanks to technology forged by the Apollo programme**

Although many have said NASA lost the momentum of humans exploring the Moon and beyond, in hindsight this diversion was perhaps a necessary step leading us to today, where we are realistically figuring out how to live and work on another planetary surface. Space is an extremely harsh environment for life and the challenges to overcome in the Apollo programme showed us how little we knew about it. This makes the achievements of the Apollo astronauts on the Moon even more amazing.

For the last 20 years, there has always been someone living aboard the ISS, which has evolved from an outpost on the edge of space into a highly capable international laboratory for research in its unique environment. We now know what space does to our bodies and how to utilise it to our advantage. By continually building on previous work in space, new results compound and new benefits materialise, aided by the continual revolution in computer and manufacturing technologies.

Pointing to hidden riches

While this half-century of research on humans living in space has produced amazing benefits, including for humanity on Earth, planetary scientists have also continued to explore the Moon. Over the last 15 years, several important lunar missions were conceived and executed that continued to ▸



▲ **Water ice in shadowed craters at the Moon's south pole, shown in blue on this diagram, has been building up for billions of years and contains volatile material from the Solar System's distant past**

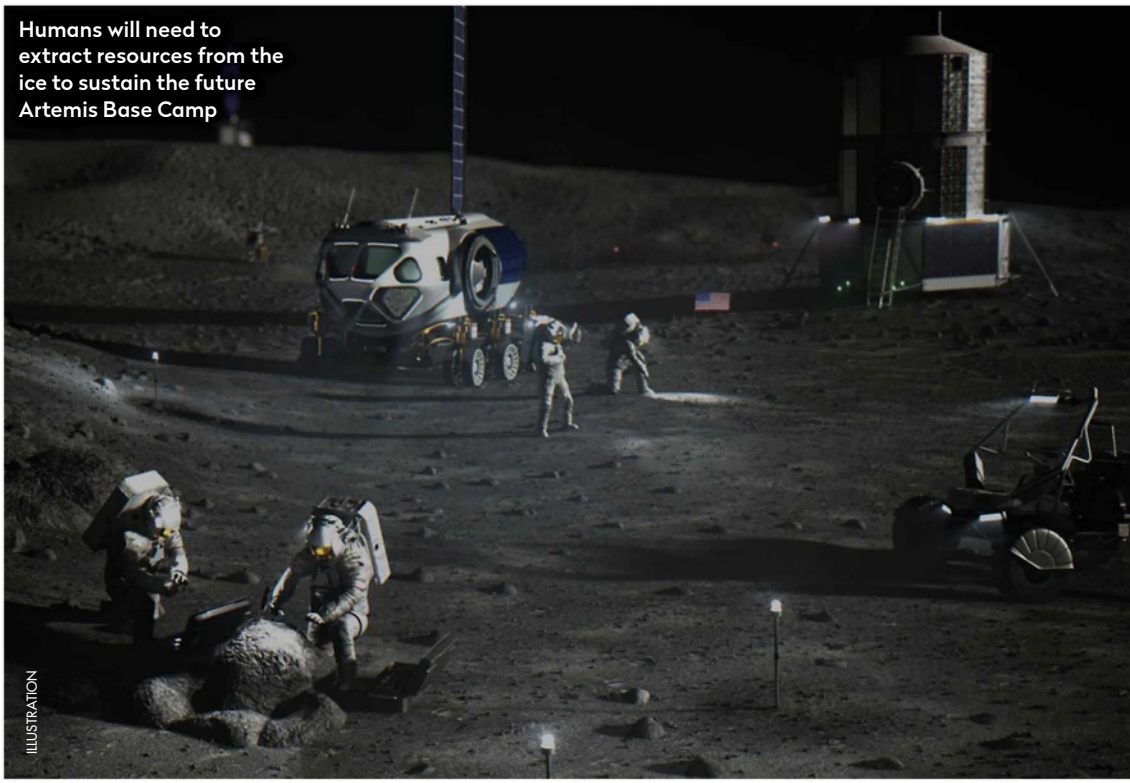
▸ investigate the puzzles that arose from the analysis of Apollo data.

For instance, a remarkable discovery was made in the lunar north and south poles. Remote sensing data from missions like the Lunar Reconnaissance Orbiter has determined that the Moon holds a significant amount of frozen water and hydroxyl in its permanently shadowed regions (PSRs). Current estimates are that there may be as much as several hundred million tonnes of frozen water here.

In addition to water, it now appears that in these regions there may also be volatiles like carbon dioxide, sulphur dioxide and nitrogen. Once these volatiles get into a PSR they will stay there, since there is no energy from sunlight to break the frozen volatiles into their components, causing them to drift away in the solar wind. We now believe that these volatiles were collected over time during important events in the evolution of Earth and the Moon.

After they formed, asteroids and comet bombardments brought water to the surface of the Moon. That process continues to this day but on a much-reduced level. Additionally, during the late heavy bombardment large amounts of molten, volcanic rock filled huge basins, creating the lunar mare and, in addition, lunar volcanos liberated huge amounts of trapped subsurface gases to create a thin, non-negatable lunar atmosphere. Over a short period of time, parts of the lunar atmosphere collapsed into the PSRs.

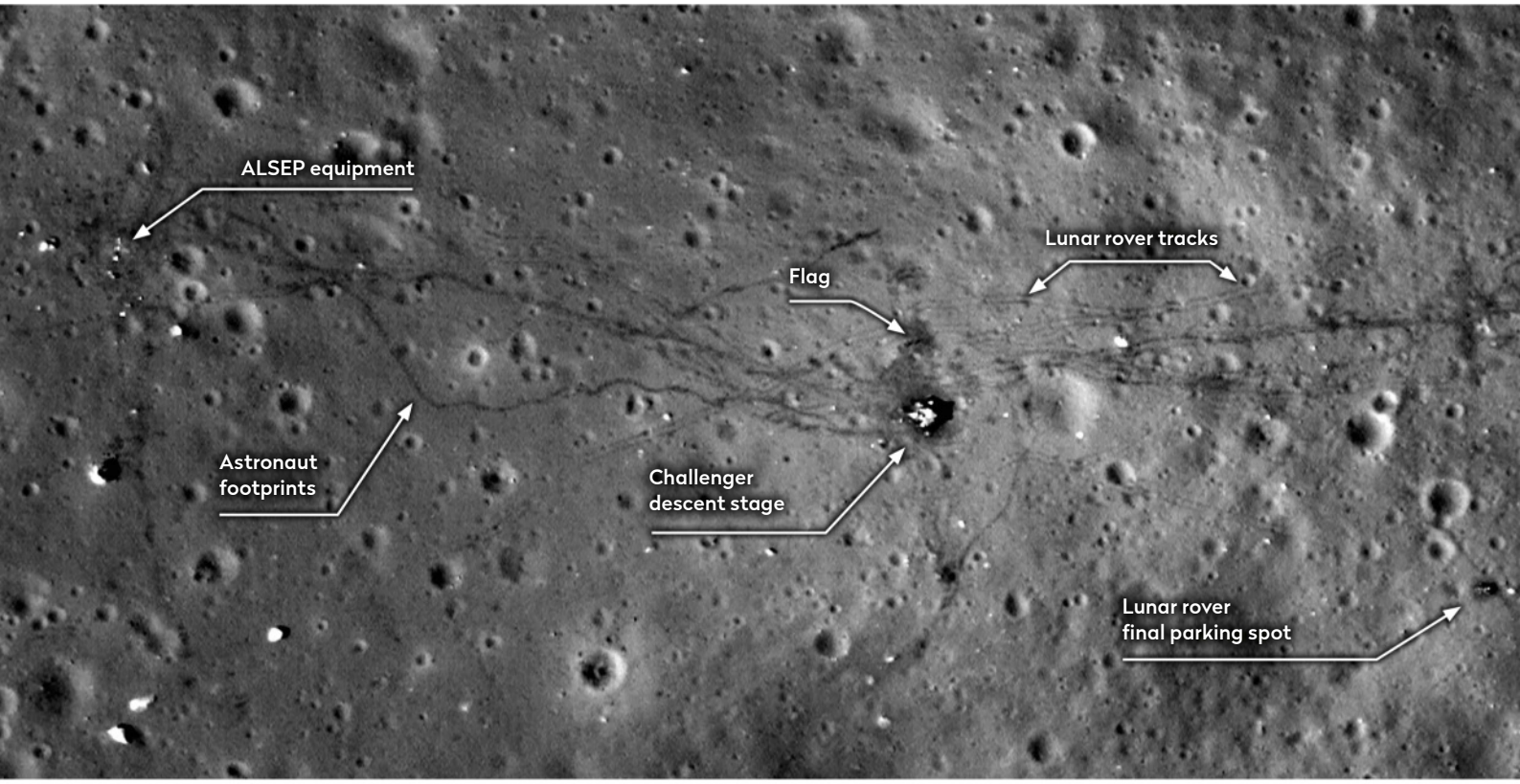
The Apollo lunar samples also tell us that the early Moon had a magnetic field for several hundred million years, protecting the early Earth's and early Moon's atmospheres from the harsh radiation from our young Sun. The magnetospheres of Earth and the Moon combined to provide a pathway for evaporation from early Earth's atmosphere to move to the polar regions of the Moon and become trapped in the PSRs.



Humans will need to extract resources from the ice to sustain the future Artemis Base Camp

ILLUSTRATION

NASA X 2, NASA'S GODDARD SPACE FLIGHT CENTER/ASU



As shown in the diagram on the previous page, volatiles can tell us about the composition of the very early asteroids and comets, the atmosphere of the early Earth, and whether the young Moon had an atmosphere. It is hard to imagine, but we now think we have found in the PSRs a time capsule of the history of the volatiles in our Solar System. Scientists want to first enter these regions and core them to provide a proper assessment of what is there. Because of the continual micrometeorite impacts on the Moon mixing the soils and creating regolith, these cores are unlikely to capture an obvious, perfect record of that time in history, but they will reveal clues available in no other way about where these volatiles came from and how they were preserved.

▲ Apollo 17's landing site, where geologist Jack Schmitt and commander Gene Cernan took humanity's last steps on the Moon in December 1972

A human return to the Moon

Why is it so important to find these volatiles for human exploration on the Moon? The simple answer is that they will allow humans to 'live off the land' as much as possible. Launching resources into space for humans to use is expensive and if we can use resources already on the Moon, our ability to stay and work on the lunar surface for long periods of time can become a reality. The water that can be extracted from a PSR can be used to drink and we can break up the water into its components and use the oxygen to breathe, along with creating hydrogen and oxygen reserves for rocket fuel.

Extracting these resources with new instruments is under rapid development at NASA and other space agencies. The yet-undetected but suspected other volatiles trapped in the PSRs will also be important. Indeed, extracting all of these volatiles for use is what we call a game-changer for the human exploration of space: if we can extract water and other volatiles for use on the Moon we can certainly do it on Mars, since it holds even greater reserves of these substances in its crust.

James L Green is a former NASA chief scientist and the longest-serving director of the Planetary Science Division in NASA. He coordinated NASA's involvement with the film *The Martian*

All of these results are feeding into NASA's plan for the next human lunar programme, Artemis. The first three missions are well laid out, with the Artemis I test flight using the new Space Launch System and the Orion capsule now targeted for the launch period of 12 November to 27 November. The uncrewed Artemis I is the first in a series of increasingly complex missions. Once it is completed, the results will be analysed before flying astronauts using the same trajectory on Artemis II. By 2025, Artemis III will land the first woman and first person of colour on the south pole of the Moon and establish long-term lunar science and exploration capabilities. NASA is planning the missions beyond Artemis III now, leading to what we call the Artemis Base Camp, a much more permanent place where we will learn to live and work on another planet.

So now, when we look at the image captured by the Lunar Reconnaissance Orbiter of the Apollo 17 landing site (see above), we can appreciate the enormous role that these early explorers played in getting us ready for the next step of human exploration into deep space. Just as it was with the Apollo programme, I have no doubt that the Artemis programme will inspire countless students to become scientists, engineers, inventors and mathematicians. They may walk on the Moon or be the explorers who venture onward to Mars and show humanity's limitless possibilities.

The fundamentals of astronomy for beginners

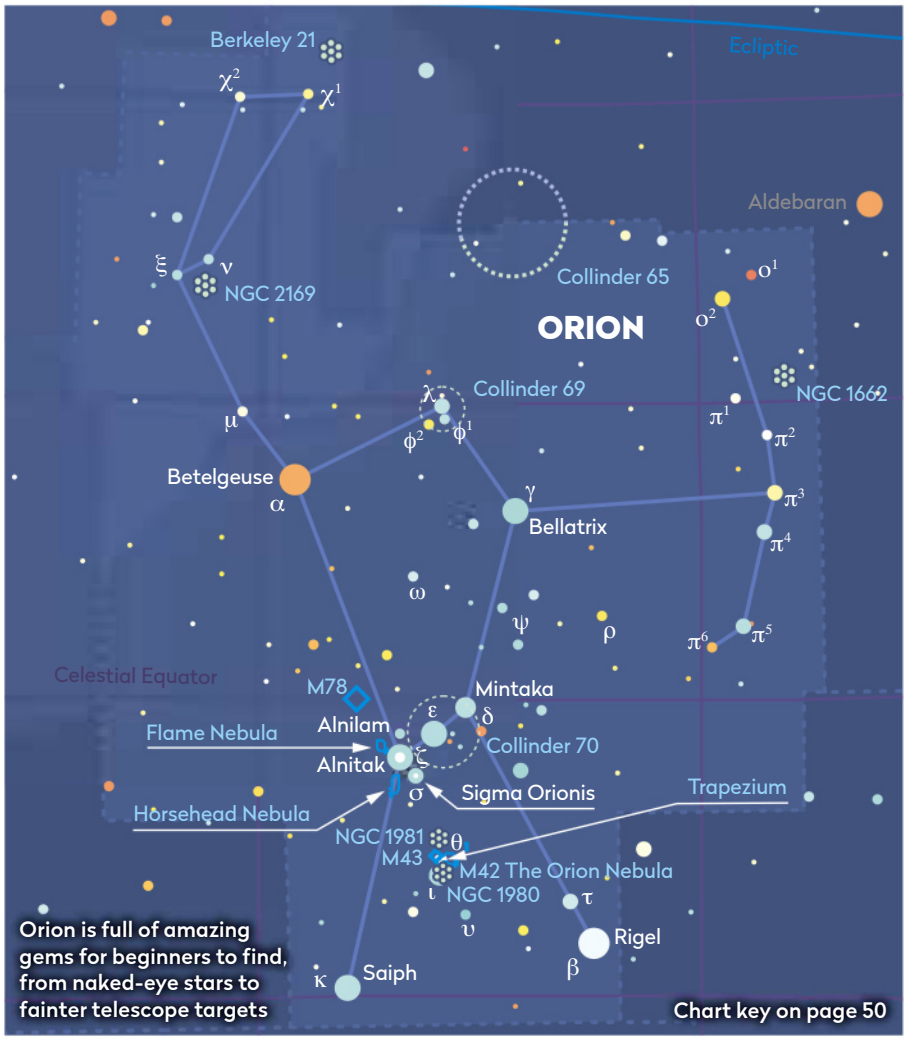
EXPLAINER

A beginner's tour of Orion

Katrin Raynor reveals the stunning sights anyone can enjoy in this winter constellation

Winter is the best time of year for newcomers to astronomy. It gets darker earlier, the atmosphere is clearer and some of the best constellations are visible in the night sky. Within these constellations you can see deep-sky objects such as galaxies, star clusters and nebulae.

Orion is one such constellation. It's a great starting point for beginners because it is instantly recognisable in the winter sky and contains wonderful stars and deep-sky objects that demand closer inspection. Here we'll explore some of Orion's astronomical treasures and how you can view them.



Orion's Belt

Orion is easy to spot because of the three stars in an almost straight line that run through its middle. These are (left to right) Alnitak, Alnilam and Mintaka, and they form Orion's Belt, an asterism (pattern of stars) within the larger constellation. Alnitak is a triple star system, Alnilam is 375,000 times brighter than the Sun and Mintaka is a binary star system (two stars orbiting each other). Orion's Belt forms part of a larger open cluster known as Collinder 70.

Betelgeuse and Rigel

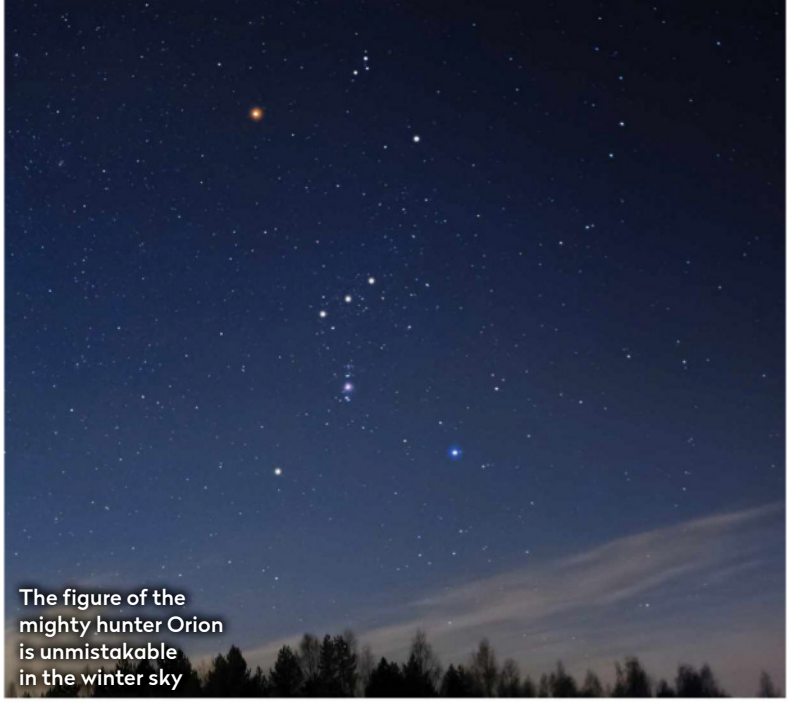
At opposite corners of the figure of Orion are its two brightest stars. Betelgeuse and Rigel are winter night-sky celebrities. Betelgeuse is a red supergiant with an orange hue that is greatly enhanced through binoculars and telescopes. A thousand times bigger than our own Sun, if you placed Betelgeuse in the centre of our Solar System it would swallow up Jupiter. In the far future, Betelgeuse will explode as a supernova, and will be so bright it will cast shadows on the ground. In contrast, icy-blue Rigel is a blue supergiant star 70,000 times more luminous than our own Sun. At a magnitude of +0.12, it is the seventh-brightest star in the night sky.

Bellatrix

The third-brightest star in Orion, Bellatrix lies in the top right corner, 5° to the west of Betelgeuse. Its name means 'female warrior' in Latin. This blue giant star, almost six times the Sun's diameter, is just 25 million years old. Shining at mag. +1.6, it is the 25th-brightest star in the sky.

Saiph

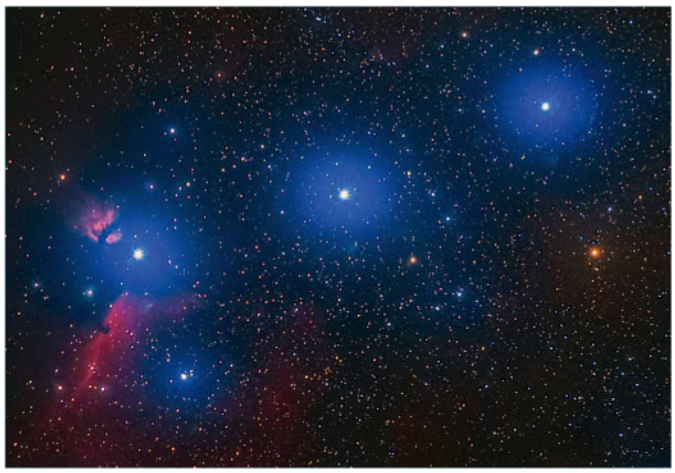
The faintest of the four corner stars of Orion, blue-white Saiph – from the Arabic word for 'sword' – is another



The figure of the mighty hunter Orion is unmistakable in the winter sky

Jewel in the crown: the Orion Nebula leaps to life through a small refractor

▲ The dusty tendrils of the Flame Nebula are a little tricky thanks to Alnitak's glare, and call for larger instruments and dark skies



▲ Orion's famous Belt (left to right): Alnitak, Alnilam and Mintaka. Bump up the aperture to see the iconic Horsehead Nebula (left)

supergiant. Although it's 56,000 times more luminous than our own Sun, its distance of around 650 lightyears reduces it to mag. +2 in our sky.

The Orion Nebula

The Orion Nebula, M42, lies in the centre of Orion's Sword, a short vertical line of three fainter stars that hangs from Orion's Belt. It looks like the middle 'star' of the sword to the naked eye, a little fuzzier than the stars above and below it. Composed of dust and gas and located 1,344 lightyears away, it can be seen with the naked eye and is a perfect pitstop for beginners. A pair of 10x50 binoculars will enhance the nebula, while a small telescope will bring out dark and light patches.

Trapezium Cluster

Embedded in the heart of the Orion Nebula, the Trapezium Cluster is a tight open cluster of stars born from the surrounding dust and gas. The cluster appears as a single starry point through binoculars, but its four brightest stars are revealed through medium-aperture telescopes. Through a large telescope, it is a stunning sight, illuminating the gas and dust behind and around it.

The Horsehead Nebula

The Horsehead Nebula is a 'dark nebula' – a cloud of dust silhouetted against brighter gas behind it. It's just beneath Alnitak, the star shining on the eastern end of Orion's Belt. If you want to see it you'll need a dark sky, a high-power eyepiece in your telescope and a Moon-free night. You'll see the nebula as a dark notch on the lighter background. Under perfect conditions, it looks like a knight chess piece.

The Flame Nebula

Somewhat overshadowed by its bigger and more famous neighbours, the Orion and Horsehead Nebulae, the Flame is a cloud of dust and gas illuminated by Belt star Alnitak. Visible as a roughly cone-shaped smudge through small telescopes, larger instruments show it cut down the middle by a dark dust lane. The nebula is a great photographic target: even short unguided exposures with a DSLR camera on a tripod will record it well.

Sigma Orionis

At the eastern end of Orion's Belt, just south of Alnitak, this fourth-magnitude multiple star is the brightest member of a young open star cluster sprinkled across the same telescopic field of view as the Horsehead Nebula. The cluster has several dozen members bright enough to be seen through a telescope. Sigma itself is a system of five stars and even a small telescope will resolve its brightest components, making it a popular target for backyard observers.

Katrin Raynor is an astronomy writer and a Fellow of the Royal Astronomical Society

Practical astronomy projects for every level of expertise

DIY ASTRONOMY

FAMILY FRIENDLY PROJECT

Make a fairy-light constellation display

An easy Christmas art project to recreate your favourite star patterns

▲ **The finished Orion wall art, unlit and lit, with nebulae like Barnard's Loop providing a splash of colour**

One of the first steps for any new astronomer is to learn to recognise star patterns. These light-up displays are a simple-to-make astronomy-themed Christmas decoration that will help you to become more familiar with your favourite constellations. They also look so stylish that you'll want to keep them up all year. They would even make a great nightlight in a child's bedroom.

The materials you need are readily available at budget craft stores or online. We chose battery-operated lights to avoid untidy trailing cables. Our lights had a remote control, but the design allows easy access to the battery pack so they can be turned on and off from there. It works better if your lights have small protruding bulbs because it is easier to poke them through the holes and secure them there. We held the lights in place with hot glue. One thing to note is that blue-rich white LED lights can disrupt your natural sleep hormones, so it is better to opt for warm white lights, especially if the display is going to be on a bedroom wall.

ALL PICTURES: MARY MCINTYRE

Mary McIntyre is an outreach astronomer and teacher of astrophotography

Creating this project offers some great learning opportunities for younger members of your family, but an adult will be needed to help with some of the steps. We chose the constellation of Orion, but you can pick whichever constellation you prefer. Marking out the stars will introduce you to the star patterns and seeing it daily will really help you to memorise it.

Add some colour

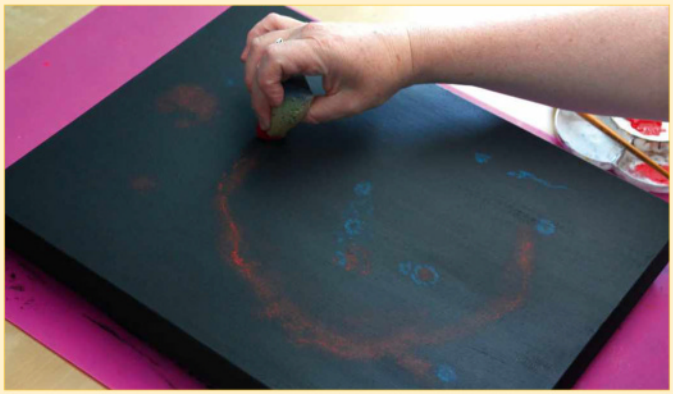
For the background, you could just paint the canvas black, but you could also look at long-exposure photos to find any areas of nebulosity and paint those on too. Orion is full of beautiful features like M42, the Orion Nebula, as well as the Horsehead, Flame Nebula and Barnard's Loop, a beautiful ribbon of nebulosity that snakes through the constellation. Including these offers an additional learning opportunity, a chance to incorporate colour and will help you to remember where these deep-sky objects are located within the constellation. It could also be a chance to teach younger family members all about molecular clouds and star-forming regions. Nebulosity painted on the background makes the canvas look beautiful even when the lights are turned off.

We made one constellation board in this DIY project, but you could create a whole series of wall art pieces of all your favourite constellations.

What you'll need

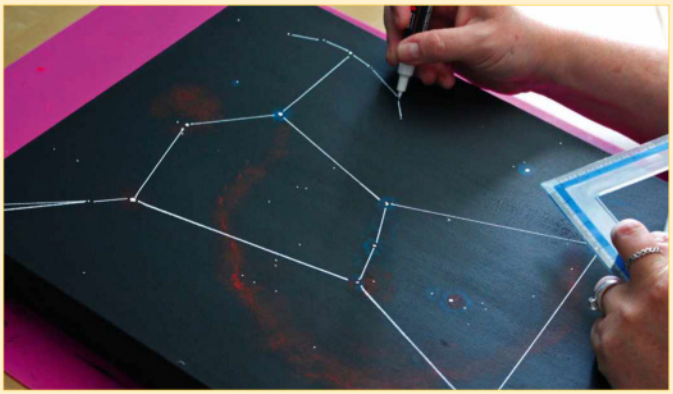
- A set of battery-operated LED fairy lights. Ours was a string of 50 lights.
- An art canvas deep enough to accommodate the lights' battery pack. Ours measured 30.4cm x 40.6cm x 3.6cm (12 x 16 x 1.5 inches).
- Black acrylic paint, plus colours for any nebulae. A white acrylic pen.
- An awl, hot-glue gun and tape to fix the fairy lights to the canvas.
- A sheet of black card about 1cm smaller than the canvas to cover the back and the fairy light wires. Ours was A3 size.
- Velcro, a staple gun and a piece of string.

Step by step



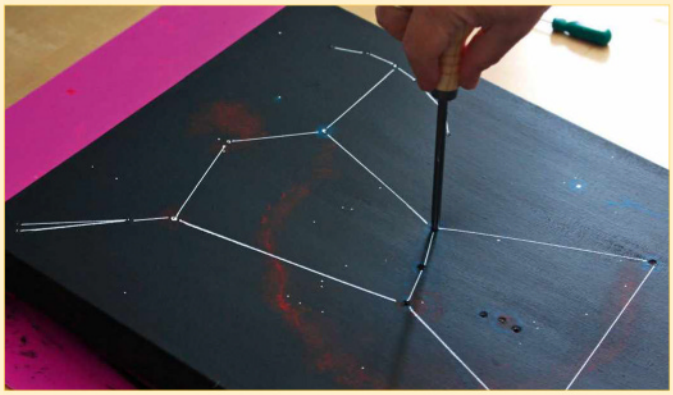
Step 1

Paint the entire canvas black (front and back) and allow to dry. Then, using a sponge or small paint brush, lightly dab appropriately coloured paints to create the areas of nebulosity, keeping in mind where your stars will be.



Step 2

Use a white acrylic paint pen to mark the constellation stars plus a few background stars. Using a ruler and the paint pen, draw the constellation lines, wiping the ruler after each line. If you don't have a paint pen, use a small brush.



Step 3

Using a sharp object such as an awl, carefully poke holes in the canvas in all places where you want an illuminated star. Make sure that the hole is only just big enough for the lights so that the fairy light bulbs fit snugly.

Step 4

From the back of the canvas, poke the lights through the holes you just made. Secure each light with a blob of hot glue, holding each one until the glue has set. Use masking tape to secure any loose bits of wire and any lights that are unneeded.

Step 5

Attach the battery pack to the bottom of the canvas frame with Velcro. If the edges of your battery pack are irregularly shaped like ours were, you can attach it directly to the back of the canvas instead of the frame.

Step 6

Cut a rectangle out of the black card where your battery pack lies, then glue or staple the card to the back of the canvas. Finally, staple a piece of string across the back of the canvas, about 10cm from the top, to act as a hanger.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Vanishing Mars

Photograph the moment the Red Planet is occulted by the Moon on 8 December

Mars will be occulted by the Moon early in the morning on 8 December, the day the planet is also at opposition. Opposition is a big deal for Mars, presenting the planet at its largest and brightest for the current period of observation – great news for anyone wanting to capture an image of this uncommon event.

The planet will be bright enough that many smartphone cameras may well be able to photograph it. If this is how you plan to record the occultation, head outside on a clear night before 8 December to see whether yours can. Some are able to detect low light conditions and adjust accordingly. If yours can't do this, see whether it offers a choice of manual camera settings either natively or via a downloadable app. A Google search of your phone's make, model and 'astrophotography' may provide advice on settings.

▲ **Whether with a smartphone, a camera with a telephoto lens or a planetary camera, you can capture Mars disappearing behind the Moon on 8 December**

Maximise your mobile

It's unlikely that your phone can capture the planet as it slips behind the edge of the Moon or out from behind it an hour later, but it may be possible to achieve this afocally by pointing your phone down the eyepiece of a correctly focused telescope at the time of the occultation. An eyepiece holder is highly recommended here and can be obtained relatively inexpensively via astronomical equipment stockists.

If you plan to use just a phone camera, consider mounting it on a tripod with an inexpensive phone holder. A headphone cable with a volume control sometimes works as a remote shutter release. Try it out in the days before the occultation by opening the camera, attaching the cable and pressing the '+' volume control to see whether your phone takes a picture.

Aim to take shots when the Moon is near to Mars either before or after the occultation – this should give the best results. If your camera has zoom capability, use optical zoom rather than digital zoom. Digital zoom takes the highest optically zoomed image and rescales it, with no advantage other than looking impressive on your phone's screen.

Photographic cameras fitted with telephoto lenses will get you in closer to the action. Below 1,000mm focal length, aim to capture the Moon with Mars as a dot nearby. Make a correct exposure of the Moon first, then adjust so Mars is nicely shown. Take a series of several images at, say, five-minute intervals leading up to the occultation. These can be overlaid, setting the upper layer's blend modes to lighten. Finally, bring these together with the properly exposed Moon shot to make a stunning rendition of the event.

Mars will present an apparent disc size of 17.1 arcseconds on the night of the occultation. Although 105 times smaller than the 1,803-arcsecond apparent diameter of the Moon, a close-up on Mars will show it as a disc. With a telephoto setup you can capture the event in its full glory, as long as you pay attention to the brightness difference between Mars and the Moon. Follow our guide opposite and see how well you can do capturing this rare and exciting event.

Equipment: Camera with fixed or tracking mount

▸ **Read more about the occultation on page 46**

Pete Lawrence is an expert astro-imager and a presenter on *The Sky at Night*

✉ **Send your images to:**
gallery@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

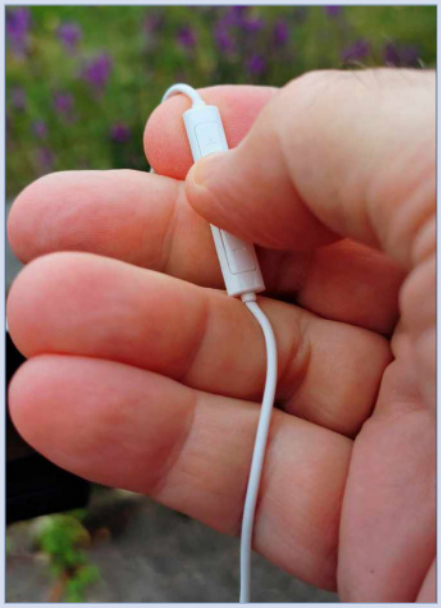
Step by step

STEP 1

Basic kit such as a smartphone can be used to photograph the occultation. Practice on a clear night before 8 December to see whether you can record the orange dot of Mars. An inexpensive phone holder tripod mount is recommended for best results. Point your camera at Mars to see whether it can automatically adjust settings for a night shot.

STEP 2

If you manage to successfully capture Mars, find the image info data (normally provided while viewing the shot) and note the settings. Work out how to set your camera's phone into manual mode to replicate the settings. A correct exposure for the Moon will record Mars as rather dim so you may need to slightly over-expose it. In manual mode, ensure focus is set to infinity.

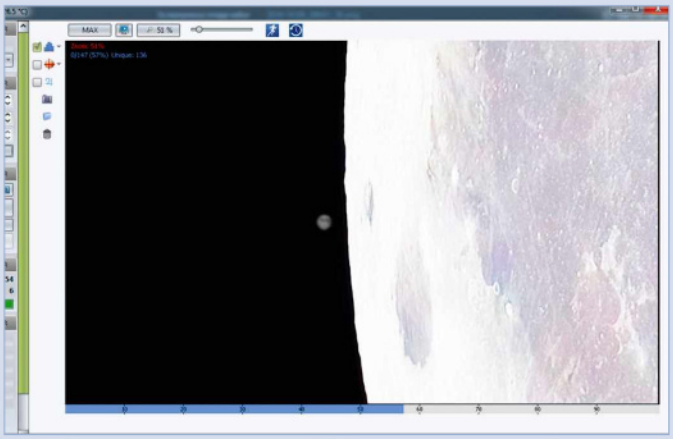


STEP 3

Alternatively, mount your phone over the eyepiece of a correctly focused telescope to take your shot. An inexpensive eyepiece holder will make the alignment required a lot easier. In-ear headphones with a volume control on the cable can sometimes work as a remote shutter release cable. Again, the best technique is to experiment on a clear night before the occultation.

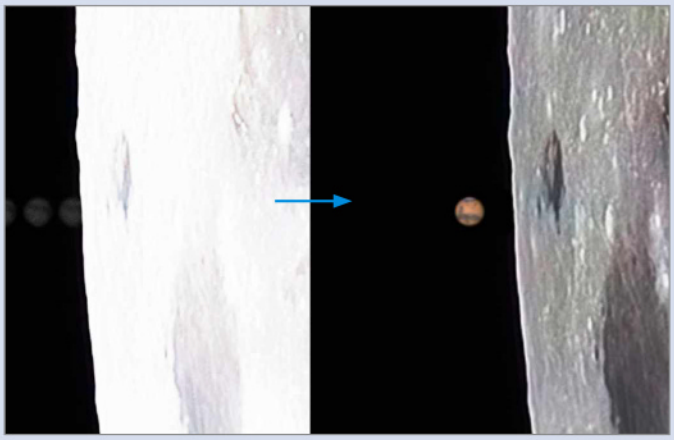
STEP 4

If you have a high-frame-rate planetary imaging setup, grab a correctly exposed image of Mars immediately before or after the occultation, either in mono or colour. A full RGB capture of Mars can be done at this time. Similarly, grab a correctly exposed shot of the Moon's surface near disappearance or reappearance too.



STEP 5

You can record Mars and the Moon's surface in the same frame; don't worry about over-exposing the Moon. The Moon's motion makes it hard to record a sequence for stacking though. Instead, record the disappearance and reappearance as a video sequence, each frame recording Mars's position relative to the lunar limb.



STEP 6

It takes around 35 seconds for Mars to disappear and to reappear. If capturing a high-frame-rate sequence, a video editor such as VirtualDub (freeware) can be used to extract frames (at 1-second intervals, say) that can then be brought together to produce a composite representing what the view looked like visually.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Handling problem greens in your astrophotos

Using a Photoshop plug-in to easily balance colours around deep-sky targets

▲ Above left: The original stacked image of the Flame, Horsehead and Orion Nebulae before applying any colour-balancing measures, captured with a William Optics RedCat 51 and Canon 6D, 18x of 3' exposures at ISO 1600, stacked in DeepSkyStacker. Above right: Charlotte's final image, processed in Photoshop using the HLVG plug-in to remove troublesome green colouration

Effective colour management can really boost your astro photos. Without it, deep-sky objects can get lost against a noisy background. This is not to say you should aim for flat, black backgrounds with white stars. That can look unrealistic and unrepresentative of a deep-space environment.

Colours in space are a tricky thing to replicate. Our cameras pick up details that our eyes simply cannot. However, their sensors – which vary greatly depending on camera type, model and age – all pick up colour differently, so the same deep-sky image can look very different from camera to camera. Some produce more colour (or chromatic) noise than others, resulting in a noisy or off-colour image to process.

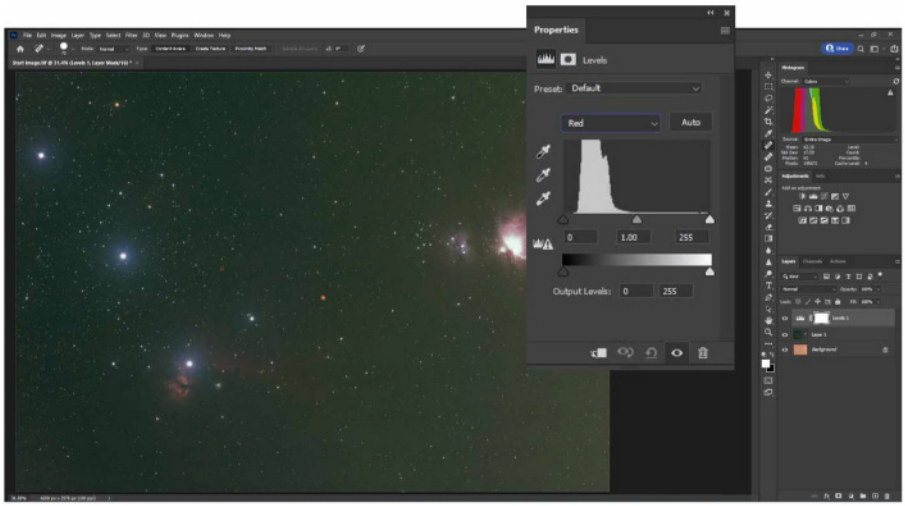
One channel that creates chromatic noise problems is green. Typically, unless imaging comets or the Northern Lights, this is one colour that astrophotographers wish to reduce or eradicate. Given that most astronomical objects do not emit visible green light, it is associated with noise, and can subdue nebulous details or discolour stars. Anything green in a deep-sky image is therefore usually an unwanted artefact we want to edit out.

Hasta La Vista, Green

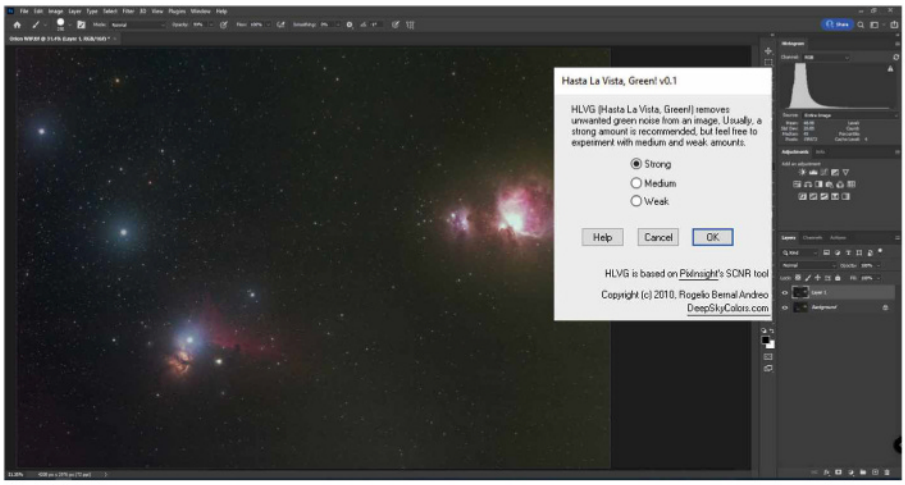
Here we will take you through the steps to use Hasta La Vista, Green (HLVG) to deal with this troublesome colour. HLVG is a Photoshop plug-in developed by Rogelio Bernal Andreo that has been around for over a decade. It is compatible with recent versions of Photoshop and it is free.

Start by downloading the plug-in from **www.deepskycolors.com/archive/2010/04/26/hasta-La-Vista-Green.html**. Locate the folder on your computer (usually in the 'Downloads' folder). This will be in a compressed format. Right-click the folder and click 'Extract All'. To move the uncompressed file into Photoshop, navigate to the Photoshop plug-in folder. This is usually somewhere like C:\Program Files\ Adobe\AdobePhotoshop2022\ Plug-ins. Drag the HLVG file into this folder. HLVG can now be found in Photoshop by clicking Filter › DeepSkyColours › HLVG.

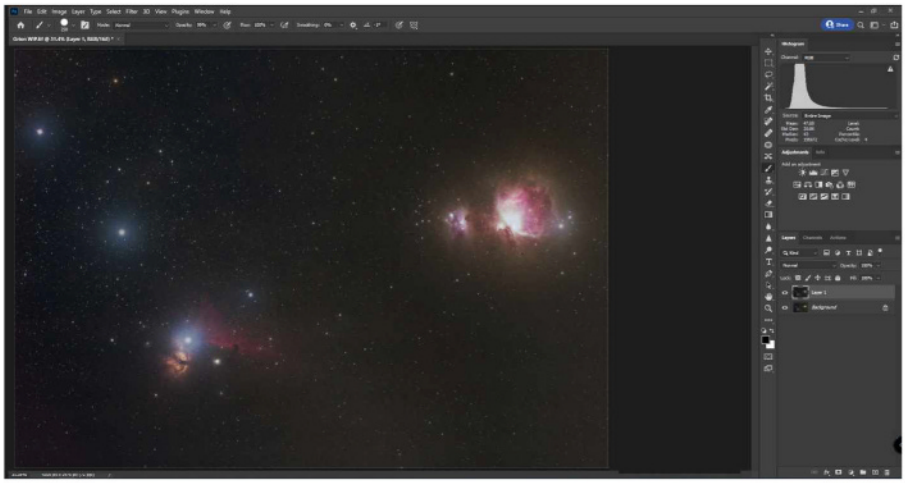
We applied HLVG to our stacked, widefield image of the Orion Nebula, captured using an astro-modified Canon DSLR. Cameras that have been modified to allow in extra 'red' infrared light can complicate the colour-balance process because our red channel has a lot more data compared to the green and blue channels. HLVG therefore comes in handy.



▲ **Screenshot 1: Before deploying the HLVG plug-in, the colour balance of the stacked image is first adjusted using Photoshop's Levels. This brings up a histogram of the image**



▲ **Screenshot 2: Having adjusted the red, green and blue channels, a distinctly green tinge still remains. Clicking Filter › DeepSkyColours › HLVG › Strong effectively removes it**



▲ **Screenshot 3: The far more natural-looking nebulae once the green tinge has been eradicated by HLVG. Further processing then produces the final image (see opposite)**

Before applying HLVG, we balanced the colours using the 'Levels' function, found at Image › Adjustments › Levels (see Screenshot 1). We ensured the histogram was set to 'Colours'. In the Levels window, we dragged each of the anchor points in the red, green and blue channels so that they touched the edge of the curves. We checked the histogram each time to make sure the red, green and blue curves were roughly the same size and sitting neatly on top of each other. We repeated this process three times by right-clicking on the Levels layer and selecting 'Merge down' so that it merged into Layer 1. We then repeated the colour balance steps again. After the third time, we started to see noise in the image, so we stopped.

Check your balance

We could see that despite balancing the colours as much as possible, our image had a distinctly green tinge to it which suppressed both the Horsehead and the Orion Nebulae. Now was the time to use HLVG. We clicked Filter › DeepSkyColours › HLVG. This brought up the plug-in menu (see Screenshot 2). Because there was still a significant amount of green, we selected 'Strong' before clicking 'OK' ('Medium' and 'Weak' options are available if you don't want to remove all the green). The green removal command was applied to our image and we could see it created a more realistic background (see Screenshot 3).

With the green now dealt with, to finish processing we made a series of final adjustments to the image's brightness and contrast (Image › Adjustments › Brightness/Contrast), vibrance (Adjustments › Vibrance & Saturation) and selective colour (Adjustments › Selective colour). To further reduce noise, we also applied Photoshop's median filter (Filter › Noise › Median) and noise reduction functions (Noise › Reduce Noise). The result, a final, naturally coloured image is on the page opposite.

3 QUICK TIPS

1. Consider using HLVG's 'Strong' setting for deep-sky nebula and 'Medium' or 'Weak' for comets or planetary nebulae.

2. Use hide all/reveal all masks to apply HLVG to the background or object only.

3. To maximise HLVG's impact, try applying it after every colour balance in 'Levels', after merging down the layer.

Charlotte Daniels is an amateur astronomer, astrophotographer and journalist

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More **ONLINE**
A gallery containing these and more of your images

The Pelican Nebula ▽

Vikas Chander, remotely via Insight Observatory, New Mexico, USA, 4–8 May 2022

PHOTO OF THE MONTH

Vikas says: "This is a popular target among astro imagers, so I wanted to do it differently. I added more Ha but also more blue, as the target seemed lacking in that filter. I wanted to keep the reds more 'bubble gum' than bright red, and I think I succeeded. 57 Cygni causes a bright halo and that was a challenge to tame. Since the filters could not be changed, I had to fight the halos in post-processing."

Equipment: FLI Proline 16803 CCD camera, Dreamscope 16-inch f/3.7 astrograph reflector, Paramount ME mount
Exposure: Ha 28x 600", L 10x 600", R 12x 600", G 20x 600", B 20x 600"
Software: PixInsight, Noise Exterminator, Photoshop

Vikas's top tips: "I spent time trying to bring out the faint nebula tendrils and tame the blue star halos. Russ Croman's excellent Noise Exterminator was used to remove noise. I don't like adding sharpness in processing and depend solely on the deconvolution process done on the luminance data to add detail and sharpness.

If I were to image this target again, I'd do something about the blue filter to minimise halos. If that's not possible I'd shoot the stars at a lower exposure time and then blend them in. Other than that, I'm quite happy with the outcome."

Milky Way over Atacama ▷

Tomáš Slovinský, Atacama, Chile, 30 April 2022

Tomáš says: "The amazing dark southern night sky from Chile. In the top left there's a faint zodiacal light called gegenschein or counterglow."

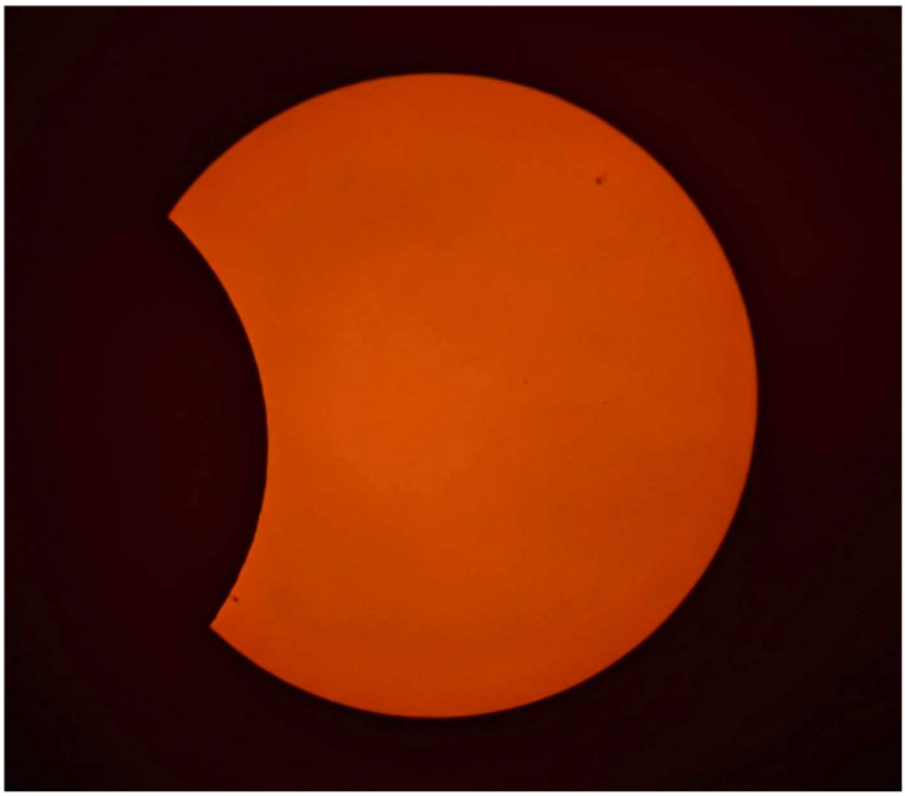
Equipment: Canon EOS 6D DSLR, Sigma Art 50mm lens, Leofoto LM-405C tripod, Sky-Watcher Star Adventurer mount
Exposure: ISO 5000, f/2.2, 25"
Software: Lightroom, Photoshop, PTGui, RegiStar

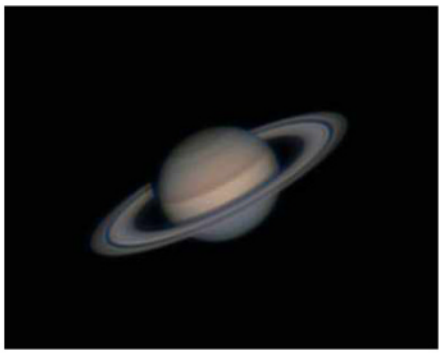
▽ Partial solar eclipse

Sonia Turkington, North Reddish, Stockport, 25 October 2022

Sonia says: "It's always a magical sight capturing nature at its best. The cloud was very thin, but I still had great viewing conditions to see it."

Equipment: Google Pixel 6 smartphone, Sky-Watcher Skyliner 250PX 10-inch Dobsonian, Seymour Solar Thin Film
Exposure: ISO 41, f/1.9, 1/31"
Software: Google Photos





△ Saturn

John Beer, Swansea, 17 September 2022

John says: "I was hoping to image Saturn at opposition [on 14 August], but weather and work conspired to stop me. However, there were favourable conditions later and I was very lucky."

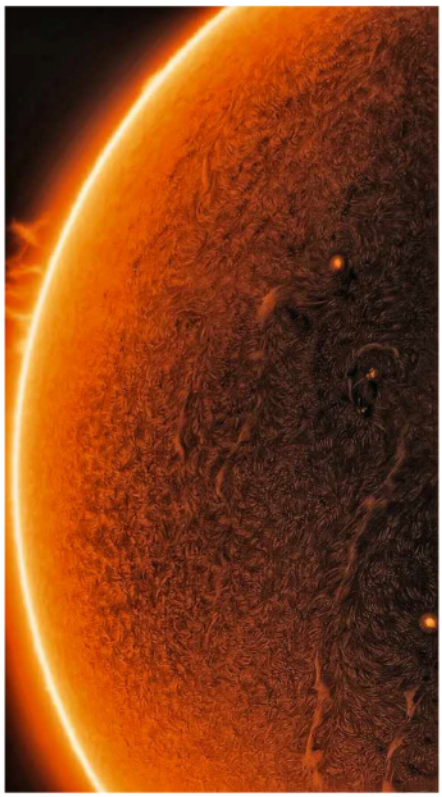
Equipment: ZWO ASI224MC camera, Celestron NexStar 8SE Schmidt-Cassegrain, Sky-Watcher HEQ5 Pro mount
Exposure: 10,000 frames **Software:** FireCapture, AutoStakkert!, RegiStax, GIMP

◁ Harvest Moon

Chirag Upreti, New York, USA, 10 September 2022

Chirag says: "My location was planned using PhotoPills. The warm, vibrant colour change as the Moon descended towards the horizon was very nice to see."

Equipment: Sony A7RIII mirrorless camera, Sony 200–600mm lens, Gitzo Mountaineer Series 2 tripod **Exposure:** ISO 160, f/11, 1/13", four frames stacked **Software:** Photoshop



△ The surface of the Sun

Joey Desmond, Dublin, Ireland, 10 August 2022

Joey says: "It was clear outside and I was trying out FireCapture. I normally do deep-sky astrophotography, so this was something new."

Equipment: ZWO ASI 174MM camera, William Optics Zenithstar 73 refractor, Daystar Quark Chromosphere eyepiece, Sky-Watcher EQ5 mount
Exposure: 3,000 frames, best 20% stacked
Software: FireCapture, AutoStakkert!, GIMP, PixInsight

▽ Occultation of Uranus

Agapios Elia and Siegfried Trattnig, Nicosia, Cyprus, 14 September 2022

Agapios says: "The enormous magnitude difference required multiple exposure sets, as well as extreme care."

Equipment: ZWO ASI224MC camera, Celestron C9.25 Schmidt-Cassegrain, Celestron CGEM mount **Exposure:** Uranus: 10' video, Moon: 1' video **Software:** AutoStakkert!, RegiStax, Photoshop

△ The ghost of Cassiopeia

Jim Owen, Swadlincote, Derbyshire, 24 September 2022

Jim says: "The ghost of Cassiopeia sits about 550 lightyears away. I've never been able to get a good moonless night to grab this very faint target, until this favourable night in early autumn."

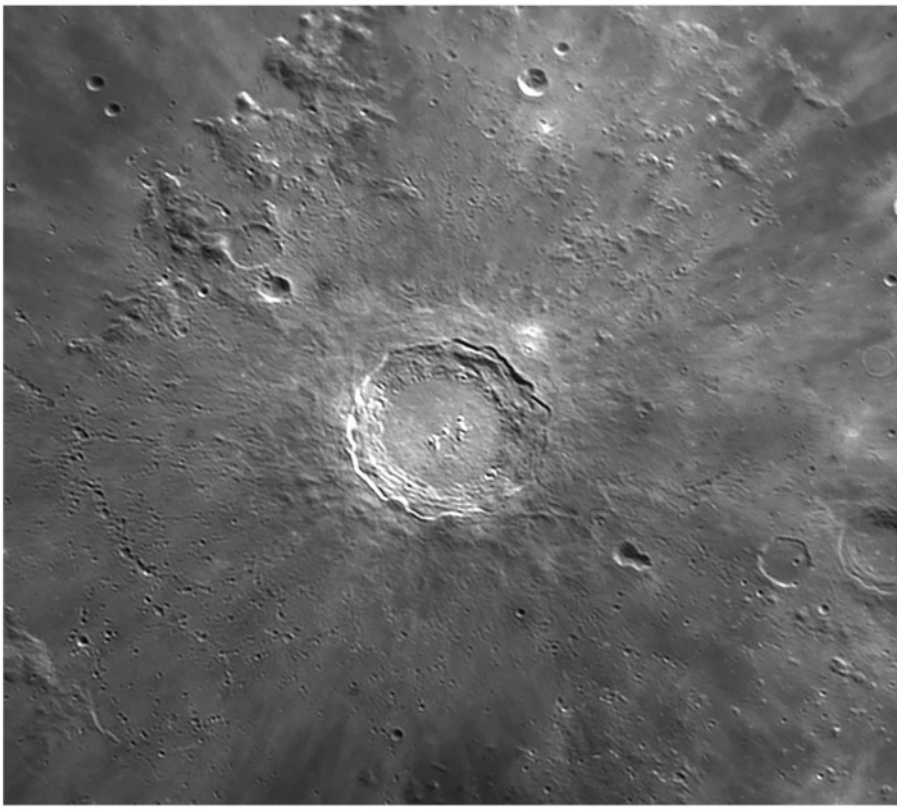
Equipment: Altair Hypercam 26C camera, Altair 8-inch f/4 Newtonian, Sky-Watcher EQ6-R Pro mount
Exposure: Ha 24 x5', OIII 24 x5'
Software: APT, Astro Pixel Processor, PixInsight

Copernicus crater ▷

Frank Dutton, King's Lynn, Norfolk, 17 September 2022

Frank says: "I've always loved lunar imaging and Copernicus is a dramatic crater. This image revealed the terrace detail and the hundreds of ejecta craterlets beautifully."

Equipment: Altair GP-CAM 290M camera, Altair 6-inch Classical Cassegrain, Celestron Evolution AZ mount
Exposure: 2,000 frames, best 50% stacked
Software: AutoStakkert!, RegiStax, Affinity Photo



ENTER TO WIN A PRIZE. HERE'S HOW

Whether you're a seasoned astrophotographer or a beginner just starting out, we'd love to see your images. Send them to us at www.skyatnightmagazine.com/send-us-your-astrophotos

hama

We've teamed up with Modern Astronomy to offer the winner of next month's Gallery a Hama lens pen, designed for quick and easy cleaning of telescope optics, eyepieces and camera lenses. It features a retractable brush and non-liquid cleaning element. www.modernastronomy.com · 020 8763 9953

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REVIEWS

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www.skyatnightmagazine.com/scoring-categories

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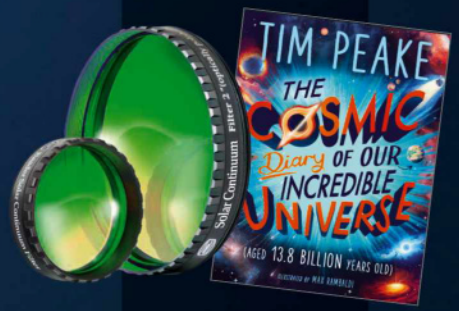
86

Is Sky-Watcher's new reflector the perfect jack-of-all-trades for new astronomers?

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

Outstanding
★★★★★
Very good
★★★★½
Good
★★★½☆
Average
★★½☆☆
Poor/avoid
★½☆☆☆



PLUS: The latest cool astro gear and new books on amazing space facts, ancient star atlases, a talking Universe and more

Sky-Watcher Explorer 130P AZ GO-2

Smartphone-controlled, beginner-friendly reflector boasting excellent views

WORDS: STEVE RICHARDS

VITAL STATS

- **Price** £379
- **Optics** Newtonian reflector, parabolic primary mirror
- **Focal length** 650mm, f/5
- **Mount** Wi-Fi Go-To altazimuth
- **Extras** Red dot finder, 25mm and 10mm eyepieces, 2-inch eyepiece adaptor, SynScan app, Vixen-style dovetail, tripod, battery box and pouch, compass, manual
- **Weight** 8.4kg
- **Supplier** Optical Vision Ltd
- **Tel** 01359 244200
- **www.**opticalvision.co.uk

Compact enough to be portable, but with enough light grasp to observe a wide range of objects, 130mm-aperture Newtonian reflectors hit the sweet spot for stargazing. Fitting nicely into this very popular spot is the Sky-Watcher Explorer 130P AZ GO-2, especially with its Wi-Fi-enabled altazimuth mount, giving it the power to seek out numerous objects using your smartphone as a controller.

The telescope's metallic black gloss finish with green highlights contrasts nicely with the mount's white powder coating, sitting on a stainless steel tripod, inviting you to turn it on and observe; we were keen to accept the invitation. Assembly of the various components was straightforward and well-explained in the printed manual, with the optical tube attaching to the mount via a 45mm Vixen-style dovetail bar. The telescope required collimation on delivery, which was quickly accomplished using our own Cheshire collimator.

The mount is fully SynScan-compatible, but doesn't come with a hand controller. Instead, you install the SynScan app on your phone and then connect that to the mount's own built-in Wi-Fi hub. Once that's done you get a convenient and intuitive on-screen interface. The mount will track objects at three different rates: solar, lunar and sidereal. The first two relate to the Sun and Moon respectively, but the third is used to track stars and other deep-sky objects.

Ready to go

To ready the telescope for observing, it is necessary to align the red dot finder with the telescope. We carried out this procedure during daytime by centring a distant object in the field of view of the 25mm eyepiece and then using the adjustment knobs on the finder to overlay the red dot on the same object. ▸

SynScan app

Instead of a conventional wired hand controller, the Sky-Watcher Explorer 130P AZ GO-2 has a built-in Wi-Fi hub, allowing it to connect to a smartphone. Compatible with iOS and Android smartphones, the app gives access to all of the mount's set-up and control features in an easy-to-use and convenient user interface. There are two versions of the app; we opted for the iOS Pro version on our iPhone SE 2020 and it operated flawlessly, although the lack of any tactile feel to the direction 'keys' meant we had to visually check our finger position from time to time.

The app contains Messier, NGC, IC, Caldwell, named deep-sky objects, named stars, double stars, Solar System objects (seven planets, Sun, Moon and comets) and a useful 'tonight's best' object listing. Overall, it gives Go-To access to nearly 11,000 objects. In addition to standard pointing duties, the app provides information about the objects being observed, including visibility times for planning your observing sessions in advance.

Rack and pinion focuser

A very basic, single-speed, straight-cut rack and pinion focuser is provided with the telescope. This example resulted in the eyepiece 'nodding' slightly when changing focus direction, which shifts the object's position in the field of view. There is a thumb screw on the top of the focuser to add tension if required.

Eyepieces

The telescope is supplied with 25mm and 10mm eyepieces, providing magnifications of 26x and 65x respectively. These were perfectly adequate for a beginner, especially the 25mm, but despite being described as 'long eye relief' they were on the margin for observing with spectacles on, even with the rubber eyecups folded down.

Red dot finder

A red dot finder with adjustable brightness is provided to help locate celestial objects. This projects an apparent red dot on the sky. Adjusting the pointing of the telescope until the star and dot are aligned with one another also aligns the telescope with the object.

Altazimuth mount and tripod

The substantial altazimuth mount can be powered by the supplied eight-cell battery box and tethered cable or by a larger 12V power bank, although no cable is supplied for this. The stainless steel tripod is light to carry but adequately stable for this size of mount and telescope, especially with the leg spreader in place.

FIRST LIGHT

▸ Keen to get acquainted with the telescope, rather than wait until nighttime we mounted our own Baader AstroSolar Safety Film filter on the front to do some observation of the Sun. We were rewarded with excellent views of sunspots AR 13057 and AR 13509 on the Sun's surface. Although removing the 1.25-inch eyepiece holder revealed a standard T2 camera thread, we were unable to focus on the Sun using our DSLR camera and adaptor. However, a planetary camera with a T2 thread and less than 30mm of back focus would be suitable for imaging both the Sun (with the correct safe filter fitted) and the Moon.

As darkness fell, we carried out the star alignment process in readiness for an observing session under the stars. This started with setting the mount to its 'home' position by levelling the tripod using its built-in bubble level as a reference, then setting the telescope tube level and pointing it to north. The supplied compass proved accurate enough to achieve this. We then connected the mount to its power supply and, with the app running on the smartphone, connected it to the mount's Wi-Fi hub. The app automatically determined our location using the smartphone's GPS location sensor, in readiness for carrying out an alignment based on two stars to build a basic pointing model.

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Wide variety of views

With the mount carefully aligned, we went in search of deep-sky objects selected from the SynScan app's extensive databases. The Go-To system easily located a range of objects, placing each one within the field of view of the 25mm eyepiece. We enjoyed excellent views of globular clusters M13, M92, M15 and M71 and then galaxies M31 and M81. We then headed to the planetary nebulae M27 and M57, the Double Cluster, and finally the double stars Albireo and Epsilon Lyrae. We couldn't resist observing the prominent planets Jupiter and Saturn, easily discerning Jupiter's bands and Saturn's rings, as well as several of their attendant pinprick moons. Finally, we turned the telescope to the quarter Moon and enjoyed some satisfying views of numerous lunar features.

The Sky-Watcher Explorer 130P AZ GO-2 ticks a lot of boxes, especially for beginners, as it is lightweight and easy to set up, with the bonus of Go-To functionality. The free SynScan app is very intuitive and might appeal in particular to younger users who are used to doing everything on their smartphones.

Optics

The telescope has a 130mm-aperture parabolic primary mirror with a focal length of 650mm, making it ideal for a wide range of observations. Parabolic mirrors are configured in such a way that they focus the light passing through the telescope to a single point, producing sharp images with no spherical aberration.

VERDICT

Build & design	★★★★☆
Ease of use	★★★★½
Features	★★★★☆
Go-To/tracking accuracy	★★★★½
Optics	★★★★☆
OVERALL	★★★★☆

KIT TO ADD

1. SynScan V.5 computerised handset and cable

2. Sky-Watcher rechargeable 17Ah power tank

3. Sky-Watcher SmartPhoto Plus camera adaptor

Opticron Oregon Observation 11x70 binoculars

Great for deep-sky observing, but steer clear of bright, high-contrast targets

WORDS: STEPHEN TONKIN

VITAL STATS

- Price £119
- Optics Multicoated
- Aperture 70mm
- Magnification 11x
- Prisms BAK4
- Angular field of view 4.6°
- Focusing Zeiss centre-focus
- Eye relief 25mm
- Interpupillary distance 57–73mm
- Weight 1.39kg
- Supplier Opticron
- www.opticron.co.uk
- Tel 01582 726522

During the past decade or so, inexpensive 70mm binoculars have become very popular among amateur astronomers. Given Opticron's reputation for good quality, we were very keen to try its Oregon Observation 11x70s.

The binoculars came packaged with a soft and slightly padded nylon case, neck strap, lens caps and rain guard, plus a separate plastic wallet which held a microfibre cleaning cloth and the instruction booklet. The booklet is generic for several types of binoculars and is written in clear, standard English.

The binoculars have a slightly matt-finish rubber armour, which allowed us to grip confidently without having to hold on too tight. The hinge, focus wheel and right-eyepiece dioptre ring all moved smoothly with enough uniform resistance to make them easy to adjust but not liable to inadvertently slip. The minimum interpupillary distance is nominally 57mm, but this will be dependent on the width of the bridge of your nose.

When you hold the exit pupils up to the light, each appears perfectly round except for a single, almost imperceptible, 'cut-off' segment. This indicates slightly undersized prisms. The exit pupils of a pair of 11x70s should be 6.4mm in diameter, but we measured these as being just under 6mm. On investigation we found that, in common with most binoculars of this class, although the physical aperture is 70mm, the light path is internally stopped down to an effective aperture of 64mm.

Optical scrutiny

Any binoculars of this size will show more when they are mounted on a tripod with an adaptor fixed to its integral mounting bush. However, these are light enough and the ▸

Bright views of faint objects

When exit pupils of an optical instrument match the size of your own pupils, you get the brightest possible image. Unfortunately, this also means you see the full effect of any light pollution. Heading to a rural site where the sky background is dark allowed us to make the most of the 6mm exit pupils these binoculars offer – granting us much brighter views of faint, large objects such as the North America Nebula, the Triangulum Galaxy and the Pinwheel Galaxy than we could see under suburban skies.

We also noted a subtle improvement in the already good colour rendition of stars and this, coupled with the exquisitely clean split into its yellow and blue components, made Albireo (Beta Cygni) particularly beautiful. Combined with the ease of holding them reasonably steady by hand, this dark-sky potential makes the Oregon Observation 11x70s an ideal pair of binoculars to take on stargazing trips away from city lights.

Multicoatings

The coating on the eyepieces and objective lenses is free of blotching, which would indicate shoddy workmanship. It gives equal reflectivity all over the surface of each lens, suggesting that it has been evenly applied. The lens surfaces only minimally reflect a bright white light, showing that the multicoating is effective.

ALL PHOTOS: @THESHED/PHOTOSTUDIO

Eye relief

The eye relief is stated as being 25mm. This is measured from the rear surface of the eye lens, which is recessed into the eyepiece housing. We measured the usable eye relief as 22mm, which we found to be more than sufficient to enable us to use the binoculars with glasses.

Prism covers

When we shone a bright light down the objective lens, we saw that the reflective surfaces of the prisms were covered with what appeared to be black plastic covers. This feature reduces the amount of stray light that can get into the optical system, where it can diminish image contrast.

FIRST LIGHT

Neck strap

The neck strap is of far better quality than is usual with this class of binoculars. Although not padded, we found the 30mm-wide webbing sufficiently comfortable for the binoculars to be slung around the neck for more than half an hour without digging in.

Eyepiece covers

The single rain guard-type of eyepiece cover attaches to the neck strap , keeping it easily accessible. Made from soft rubber, it protects the eyepieces from dew and debris when not in use, meaning you need to clean them less often.

KIT TO ADD

1. Slik Pro 400DX three-section tripod

2. Slik SH-707SP tripod panhead

3. Opticron Pro Series lens cleaning cloth in pouch

▸ magnification is low enough for them to be hand-held for short periods. We focused the binoculars and found that the central third of the image was very crisp, but star images deteriorate noticeably outside this, showing coma and, near the periphery, astigmatism. Collimation was well within acceptable tolerances. There is a tiny amount of pincushion distortion; this removes the disconcerting illusion that the sky is the surface of a ball that appears to roll as you pan across it. All bright stars are surrounded by a faint halo, which is most probably due to light scatter inside the prisms. On-axis colour correction is good, but there is distinct chromatic aberration when you observe bright, high-contrast targets like the Moon or Venus even slightly off-axis.

Touring the deep sky

These binoculars are specified as being 'multicoated', which usually means that, unlike the objectives and eyepieces, the prisms are uncoated, resulting in intrusive ghost images when we observed the Moon. Apart from this, stray light is well controlled and we were unable to get spurious images from bright stars held just outside the field of view, indicating that the rudimentary baffling is adequate.

Bright Solar System objects are not the intended target of this sort of instrument so, once the Moon was out of the way, we looked farther afield. Our first target was the Andromeda Galaxy, M31: it filled the central 'sweet spot' of the field of view, where it showed a more abrupt cut-off in brightness at its northwestern edge, indicating the presence of the dust lane there. Our next target was the often difficult Triangulum Galaxy – in this case it was an easy spot under dark skies.

Next, we took a tour around the Milky Way. The Auriga clusters – M36, M37 and M38 – were easy to distinguish from each other in size and brightness. The Dumbbell Nebula in Vulpecula was compact and bright with a rectangular appearance. Open cluster M39 in Cygnus can be difficult to distinguish from the background sky at higher magnifications, but in our test it was obvious, as were dark nebulae such as the Northern Coalsack. The double star Delta Cephei (separated by 22 arcseconds) showed clear dark space and beautiful colour contrast, while Herschel's Garnet Star (Mu Cephei) was a stunning deep orange-red.

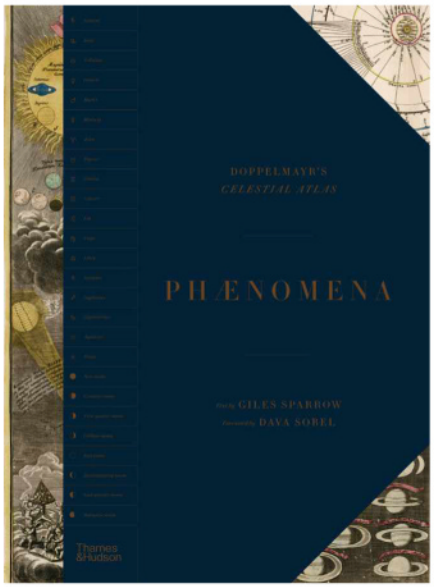
Overall, then, this is a very competent entry-level binocular for anybody who wants ultra-portable and wide-angle views of deep-sky objects.

VERDICT

Build & design	★★★½☆
Ease of use	★★★★½
Eye relief	★★★★½
Features	★★★★½
Optics	★★★½☆
OVERALL	★★★★½

New astronomy and space titles reviewed

BOOKS



Phænomena

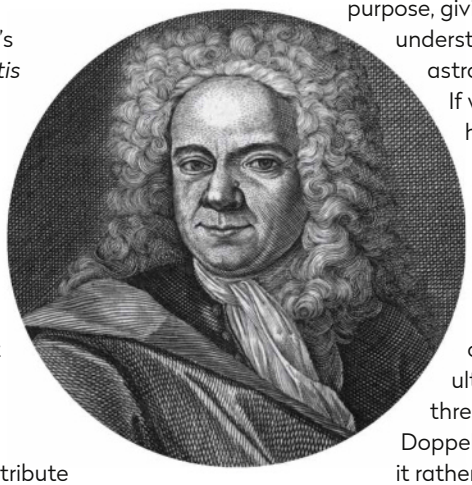
Giles Sparrow
Thames & Hudson
£50 ● HB

Johann Doppelmayr's original *Atlas Coelestis* was first published in 1742, bringing together (as the introduction to this new volume explains) astronomical theories and areas of interest important to the European Enlightenment. *Phænomena*, Giles Sparrow's wonderful tribute to Doppelmayr's important work, is stunning, enormous and filled with the most amazing illustrations.

The book is broken down into 30 sections – one for each plate of Doppelmayr's original atlas – each giving a brief history of the ideas presented therein. Often these contain explanations of Doppelmayr's astronomy and are full of terms included in a glossary at the back of the book. To take one as an example, plate 27 shows the paths of various comets superimposed onto a map of the Northern Hemisphere. The preceding text describes, with illustrations, the history of comet observations and theories about their orbits and composition. The plate is reproduced across a double page, with the subsequent pages showing close-ups of different parts of the plate and explaining them. There then follows some historical illustrations of comets.

The whole book concludes with a 'legacy' section, discussing what came next in European astronomy in the years that followed. The very back of the book contains a linear history of the 'milestones of astronomy' and a table of significant people (although only one woman).

This book is wonderful to look at. The plates are large enough that you can see a tremendous amount of detail, making it truly fascinating. The detailed explorations of each plate are excellent too, explaining each aspect and its purpose, giving a visual understanding of the astronomy involved.



Johann Doppelmayr's renowned *Atlas* featured exquisite illustrations of the heavens

If we were to be picky, however, the text perhaps attempts to do too much. It tries to teach the reader astronomy, outline a linear progressive history of astronomy and ultimately link these threads back to Doppelmayr, which makes it rather dense.

Phænomena is not only an expanded and annotated reproduction of a historic astronomy text, it could also appeal to those interested in astronomy, history or art. This is a beautiful book that anyone could pore over for hours. ★★★★☆

***Emily Winterburn** is a writer and historian of science*

NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE

Interview with the author
Giles Sparrow

Why is Doppelmayr such a big figure?

He isn't a name in the same league as Copernicus or Kepler, probably because he doesn't have a particular 'discovery' to his credit. But he should be better-known for his promotion of the idea of a Sun-centred Solar System and vast cosmos beyond. His *Atlas* helped cement this by showing how accurate it was for predicting the motions of stars and planets. It's also a fascinating summary of all the competing theories of the day.

How accurate was his work?

The *Atlas*'s star maps and depictions of the planets drew on the best observations at that time: they're a time capsule of the 'state of the art' in the early 18th century. But the theory he promoted still stands up.

Isn't it a shame all star charts don't look like his?

Absolutely! As someone who has worked on a lot of illustrated astronomy books, it's fascinating to see how Doppelmayr and his team faced similar challenges, finding ways of illustrating their view of the cosmos that were not just instructive but beautiful. They even found room for the occasional joke!

What did you learn writing the book?

I was surprised how much space he dedicated to rival theories, and how protracted the shift to a Sun-centred model was. We think Copernicus had the idea, Galileo proved it and everyone sensible accepted it. But rival theories weren't just based in dogma: they were often better, more 'scientific' explanations for the evidence available at the time.

***Giles Sparrow** is the author of several astronomy titles*

The Milky Way Smells of Rum and Raspberries

Jillian Scudder
Icon Books
£12.99 ● HB

The media loves sensational headlines. When 'Oumuamua visited our Solar System briefly in 2017 and seemed to speed up slightly as it departed, the press had a field day. It could only be an alien spacecraft! It wasn't. To make such a claim you need to prove that all other possible explanations have been discounted and, with only two weeks to observe this visitor from space, that was certainly not the case.

This book digs into this and many other weird facts about our Universe, and drills into the science behind such outlandish phenomena as diamonds raining down on Neptune, supermassive black holes that can sing, that the Universe is beige and the centre of our Galaxy smells like a cocktail bar. It's a guided tour of some of the most bizarre places in the Universe. Each short chapter explains how such discoveries were made and researched. The writing is light-hearted and chatty, with jokey footnotes scattered throughout, but the science is rock-solid. There are useful links to published research papers at the back of the book to support the claims.

We learn that the Milky Way is thinner than a credit card, some galaxies look like jellyfish, that Europa may glow in the dark and that you could grow turnips on Mars but, sadly, not potatoes.

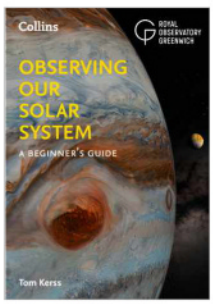
This book is for anyone who likes to astound their friends with amazing facts, backed up by science. Our Universe may be beige, on average, but it is definitely not boring. ★★★★☆

***Jenny Winder** is a science writer and broadcaster*

Observing Our Solar System: A Beginner's Guide

IDEAL FOR NEWBIES

Tom Kerss
Collins
£8.99 ● PB



After reading *Observing Our Solar System*, it was hard to believe that the main text is just 100 pages long. This thin paperback by popular astronomer Tom Kerss is such an informative and concise read that any beginner would be wise to grab a copy. Within seven chapters he has packed each page, covering topics from the history of Solar System observation to how you can tackle imaging the night sky. The chapter on observing the Moon and planets is crammed with information about what to look for and how. Use this in conjunction with the brief but informative chapter on what software to use for planning your observations and you'll be well on the way to finding your way around the Solar System.

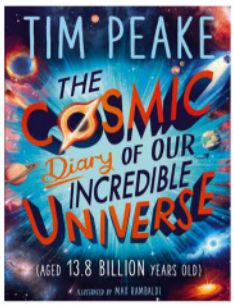
For a closer look at the planets, Kerss introduces the use of optical aids, including the types and uses of binoculars and telescopes. If you fancy a stab at imaging the planets, even with a smartphone, he reveals what to use and how to process your images. High praise must be given for the photographs and diagrams that appear on each page: beautifully clear, accompanied with simple but to-the-point text.

Kerss knows that our Solar System isn't just about the planets, and he explores this in later chapters, describing the sights and special events you can look out for, including comets, Earth's shadow and satellites orbiting overhead. How he has packed so much in I do not know, but whatever his secret, it works. ★★★★★

***Katrin Raynor** is an astronomy writer, podcaster and communicator*

The Cosmic Diary of Our Incredible Universe

Tim Peake
Hachette
£12.99 ● HB



One of the first things a writer decides when writing a book is the point of view. This is the first book you may have read written from the point of view of the Universe – and the Universe with the voice of a 10-year-old child at that!

Tim Peake's *Cosmic Diary* is a chronicle of the cosmos from the Big Bang onwards. Its playful diary format, with interjections from experts and cosmic curiosity fact boxes, makes for a fun read. It covers topics – including cosmic inflation, nuclear fusion and dark matter – that might be tough for a young audience, but does so with ease.

The book uses perfect analogies to illustrate difficult concepts. To explain cosmic expansion it asks the reader to imagine themselves in a ball of dough with raisins rising in an oven; "wherever you sit, the raisins would seem to be moving away from you in all directions."

It knows how to draw kids in. What links the Cosmic Microwave Background with pigeon poo? It turns out that a 'hiss' astronomers in 1964 attributed to pigeon ablutions on their antennae was actually the first light of the Universe from 13.8 billion years ago. At times, though, I struggled with the childlike personhood bestowed on the Universe. "I got into a massive fight today," starts the diary entry at 'Less than 1 second old'. "I got caught up in this crazy battle between two rival gangs: matter and antimatter."

I sought a second opinion from my 11-year-old. It turns out I'm just a stuffy adult. "It's entertaining," she said. "It's what kids want – it makes you want to read." Enough said. ★★★★☆

***Shaoni Bhattacharya** is an astronomy and science writer*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Benro Polaris electric tripod head

Price £1,199 • **Supplier** 365 Astronomy • **www.365astronomy.com**

ADVANCED Connect it to your DSLR and this device can transmit your images via Wi-Fi. The supplied app then uses this as a live feed to help you steer the tripod head and achieve the perfect composition. An advanced model can connect to mobile networks for remote use.

2 2-inch Baader 7.5nm solar filter

Price £198 • **Supplier** The Widescreen Centre • **www.widescreen-centre.co.uk**

Increase the sharpness of your solar images with this filter. Centred on the wavelengths our eyes are most sensitive to, the filter supresses the effects of atmospheric turbulence. Must be used with a white-light solar filter. Also comes in a 1.25-inch size.

3 Dare Mighty Things umbrella

Price $43 • **Supplier** Science Socks • **www.sciencesocks.co**

Remember the historic landing of Perseverance with this umbrella that shares the striking red and white pattern of the Mars rover's parachute – a secret code, spelling out 'Dare Mighty Things', the motto of the Jet Propulsion Laboratory that built the rover.

4 Oklop bag for mounts

Price from £32 • **Supplier** First Light Optics • **www.firstlightoptics.com**

Keep your mount secure in a bag designed to perfectly accommodate the foam packing that originally came with your mount. Available for a range of mounts (Star Adventurer Pro shown).

5 Sky quality map of Europe

Price £14.90 • **Supplier** Astroshop.eu • **www.astroshop.eu**

Satellite data showing light pollution across the continent is laid over a travel map showing major roads, train lines, towns and rivers, helping you to plan your trips to Europe's darkest skies.

6 Celestron smart dew heater controller

Price £332.99 • **Supplier** Harrison Telescopes • **www.harrisontelescopes.co.uk**

Power up to two dew heaters perfectly with this controller and its built-in 12V DC battery. Sensors measure the temperature of your optics, turning the heaters on only when needed, helping to save power.

FROM THE MAKERS OF BBC Sky at Night MAGAZINE

The Astronomer's Yearbook 2023

For an indispensable guide to the astronomical year ahead, don't miss *The Astronomer's Yearbook 2023*. Month by month, our guides and sky charts lead you through the must-see sights. From stars, galaxies and planets to meteor showers, moon transits and comets, we give you the know-how you need to make the most of your equipment and your time under the stars. Whether it's rare conjunctions and occultations or each season's best constellations, you won't miss a thing. Packed with equipment advice, challenges to set yourself, how-tos and astrophotography tips too, this is the expert practical guide you won't want to be without.

Chris Bramley,
Editor, *BBC Sky at Night Magazine*

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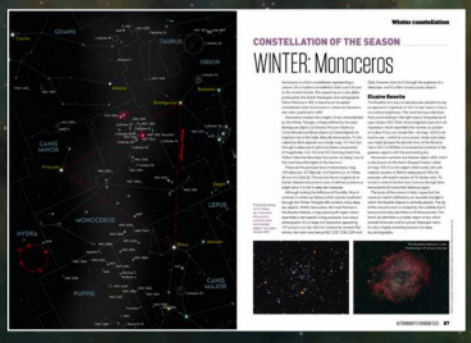
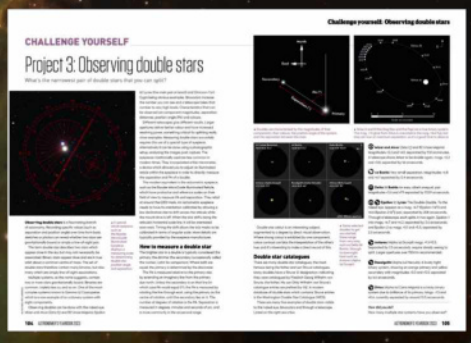
Our month-by-month guides and detailed star charts reveal what to look for and when, from stars and planets to Moon phases and more



Get to know the stand-out constellations of each season, as we highlight their brightest targets and how to best observe them



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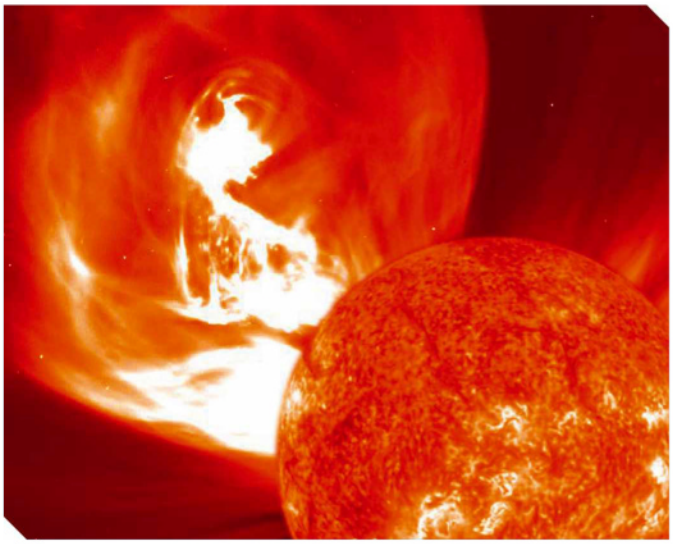
TERRY HANCOCK

Melissa Brobby interviews Ravindra Desai

Q&A WITH AN EXTREME SPACE WEATHER SCIENTIST

They can destroy satellites, disrupt communications and knock out power grids, so predicting coronal mass ejection strikes is vital to our connected world

What causes coronal mass ejections (CMEs)?
Coronal mass ejections periodically erupt from the solar surface, triggered by unstable magnetic field conditions. Their occurrence varies over an 11-year solar cycle of increasing and decreasing activity. They can reach a peak of over 10 CMEs per day during solar maximum. The next solar maximum will be in around 2025 or 2026.



▲ **Computer modelling tries to forecast when, where and how fast CMEs – colossal expulsions of plasma and magnetic fields from the Sun – could hit Earth**

SOHO (ESA & NASA)

Why is it important for us to study CMEs?
When CMEs impact Earth, entire radiation belts, which are zones of energetic particles surrounding our planet, can be rapidly destroyed or lost. My research looks at how to model this process using supercomputers and aims to use these models to aid in forecasting and mitigating these extreme events.

How much of a risk do they pose to us?
In 1859, a series of fast CMEs struck Earth during a solar storm now known as the Carrington Event. This triggered aurorae as far south as Cuba and Columbia, wreaking havoc with the world's telegraph systems at the time. If such an event occurred today it would cost the world's economy trillions of dollars, with widespread power outages and loss of satellite services affecting communications, financial transactions, traffic management and more. In fact, an event thought to be comparable to the Carrington Event occurred in 2012, but narrowly missed Earth by two weeks. More recently, in Feburary this year a solar storm disabled 40 of SpaceX's Starlink satellites.

How are you creating simulations of extreme space weather events?
I'm using high-performance computing simulations, which themselves are rapidly increasing our capability to solve complex differential equations that describe the Sun–Earth system. I'm also using data from the latest satellite missions – Solar Orbiter and Parker Solar Probe – and will be using instruments on board the Lunar Gateway Space Station, which is set to be humanity's first space station in lunar orbit. The instrument suites on board the Gateway will feature radiation detectors both inside and outside to measure the ambient radiation environment, how the Gateway structures will shield astronauts from radiation and what the biological effects of different types of radiation are at different locations within the station.

Ravindra Desai is a scientist at University of Warwick, whose research focuses on how extreme space weather events occur and how we can better predict them

Will your simulations help improve future space weather forecasting?
I'm working closely with the Met Office, which is one of three centres worldwide producing 24-hour space weather forecasts, and my current project is delivering some results from our model to help them forecast extreme events.

Could this grow our understanding of exoplanets subjected to more extreme weather?
In recent years, thousands of exoplanets have been discovered orbiting other stars. A key question now is can they hold life? The Earth's magnetic field shields us, partially, from CMEs. It is believed that Mars's once-thick atmosphere was stripped away due to the planet being unable to sustain an intrinsic magnetic field. There have been some indications that some exoplanets have magnetic fields. Modelling these will be key to understanding the stability of these planets' atmospheres and whether they might be able to sustain life.

Is this work going to mitigate the dangers facing future missions to the Moon?
Space weather events can have adverse effects on astronauts due to radiation exposure. Understanding and being able to forecast extreme space weather events will aid a new era of crewed exploration beyond Earth. The Lunar Gateway will be used to return humans to the lunar surface and act as a staging point for deep-space exploration. We will examine the radiation environment surrounding it to assist crewed missions travelling to the station and beyond. It will be a major focus in the coming years, as there will be a massive intersection between space weather and lunar exploration.

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

This month, Mars is at its best and we seek out galaxies and a cluster off the tip of the Triangulum

When to use this chart

1 Dec at 00:00 AEDT (13:00 UT)
15 Dec at 23:00 AEDT (12:00 UT)
31 Dec at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

DECEMBER HIGHLIGHTS

Mars is fascinating, being the only planet we can see surface features on. Dark and light regions betray the presence of mountains, valleys and plains. The best time to see it is at opposition. This happens on 8 December, when the planet reaches 17.1 arcseconds in diameter. Because Mars's day is 40 minutes longer than Earth's, if you observe at the same time each night, in five weeks you'll have seen the whole globe, although occasional dust storms may make it challenging!

STARS AND CONSTELLATIONS

This time of year may lack majestic winter Milky Way views, but there's no shortage of brilliant luminaries. High in the south are the somewhat isolated stars Achernar (in Eridanus) and Canopus (in Carina). Heading northward there is Sirius (in Canis Major) and Procyon (in Canis Minor), the alpha stars to Orion's hunting dogs. Orion himself contributes Betelgeuse and Rigel. Below the Hunter is Capella. That's seven of the top 10 brightest stars, all well-placed to see by late evening.

THE PLANETS

A banquet of planets this month! Twilight sees the return of Mercury and Venus, although Mercury's visit is short-lived. They are only 1.4° apart on 29 December, with Saturn higher up in the west, setting around 22:30 mid-month. Saturn is followed by Jupiter and Neptune, both retiring around midnight. Departing Uranus can be found due north around the end of twilight mid-month. With Mars at opposition you have all night to see it, with the planet transiting around midnight.

DEEP-SKY OBJECTS

This month, a trip to the Triangulum constellation. Starting at the triangle's 'point', 2nd-magnitude Alpha Trianguli, move 2.5° south-southwest to discover the galaxy NGC 672 (RA 01h 47.9m, dec. +27° 26'). This mag. +10.8 spiral stands out, with its bright halo (3.5'x1'), uniform brightness and small oval-shaped core orientated roughly east–west. Only 8 arcminutes southwest lies IC 1727. This spiral, at mag. +11.5, has a much fainter surface brightness, a smaller oval halo (1'x2.5') and tiny core, compared to NGC 672. The galaxies are orientated at a right angle. Only 0.6° southeast is the open cluster Collinder 21 (RA 01h 50.2m, dec. +27° 04'). This compact cluster (6 arcminutes across) is best observed at low power, with stars ranging from 8th to 12th magnitude, with the brightest dozen arranged in a 'C' shape. Can you get all three objects in the same field of view?

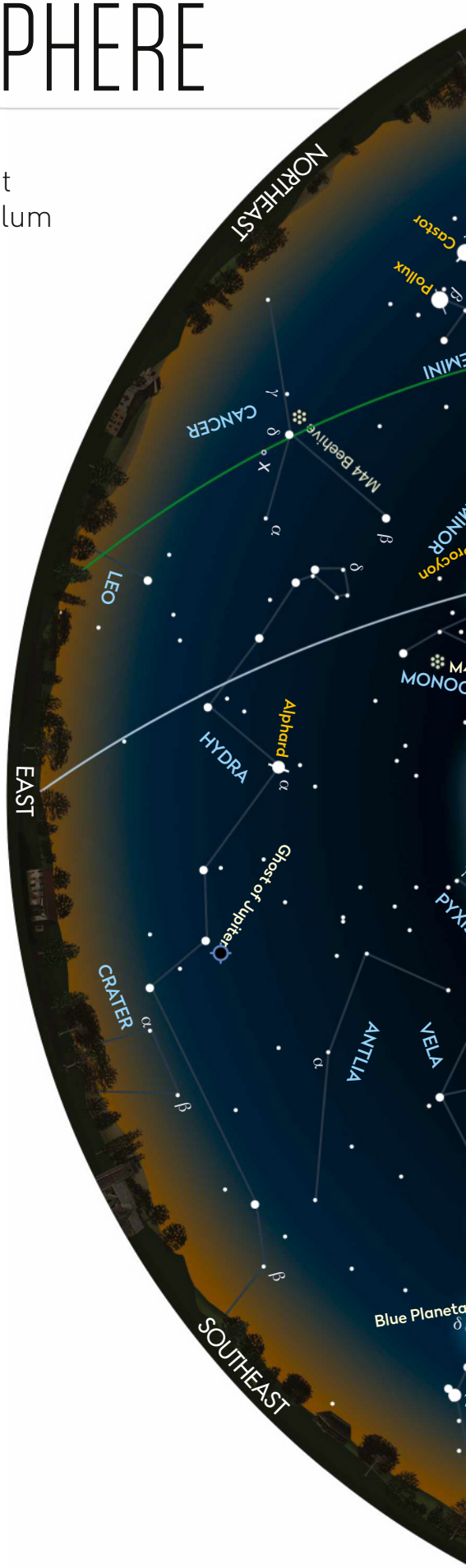
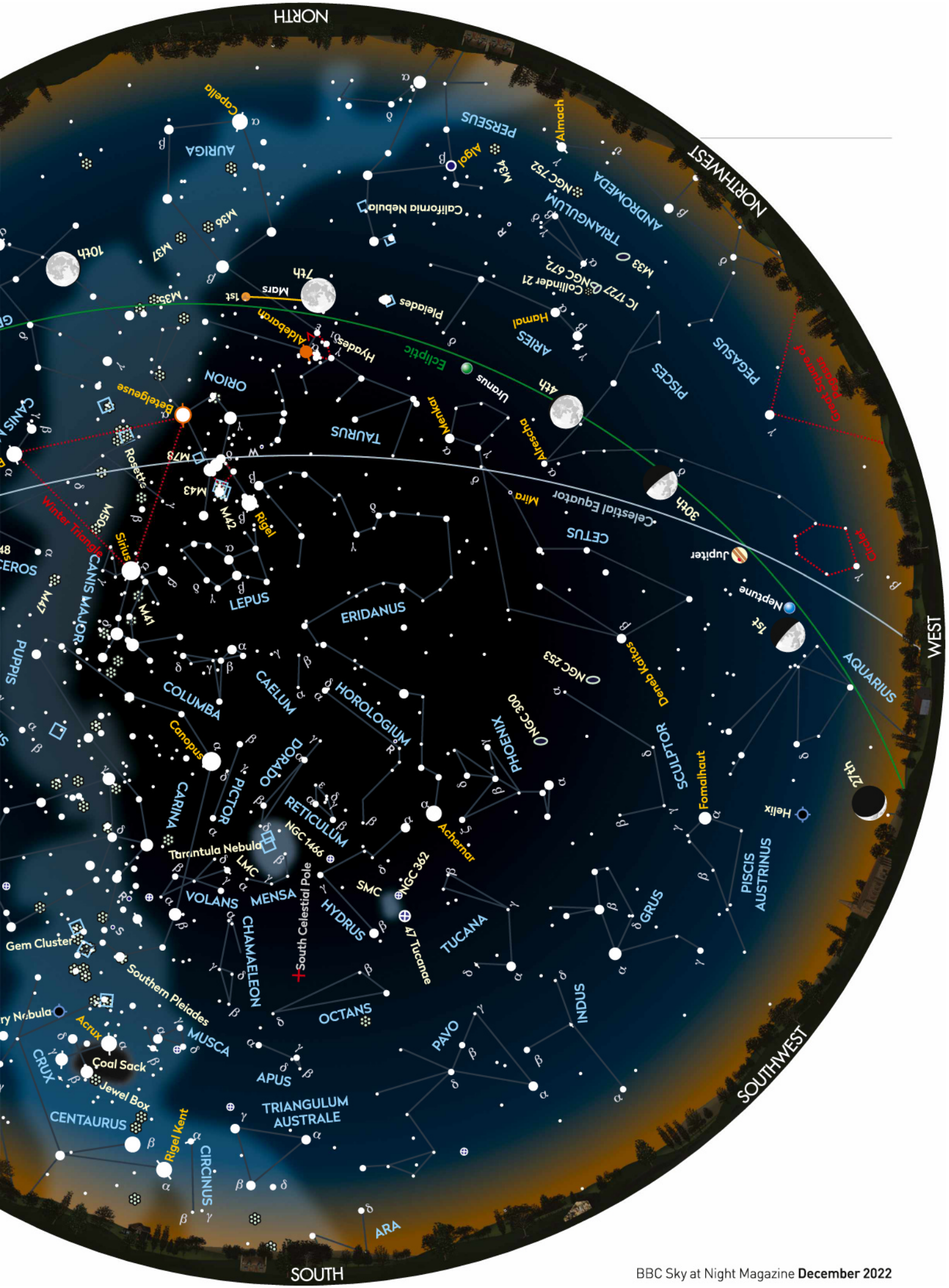


Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
Capella
AURIGA
PERSEUS
Algol
Almach
M34
NGC 752
ANDROMEDA
TRIANGULUM
California Nebula
M33
M36
M37
10th
7th
Mars
1st
IC 1727
Collinder 21
NGC 672
Pleiades
Hamal
ARIES
Aldebaran
Hyades
Ecliptic
Uranus
4th
PISCES
PEGASUS
Great Square of Pegasus
ORION
Betelgeuse
Menkar
Alrescha
TAURUS
M78
Rosetta
M43
M42
Rigel
Winter Triangle
Sirius
CANIS MAJOR
Celestial Equator
Mira
30th
CETUS
Jupiter
Circlet
Neptune
1st
LEPUS
ERIDANUS
M41
M47
PUPPIS
COLUMBA
CAELUM
HOROLOGIUM
NGC 253
Deneb Kaitos
AQUARIUS
Canopus
DORADO
PHOENIX
NGC 300
SCULPTOR
Fomalhaut
27th
Helix
CARINA
PICTOR
RETICULUM
NGC 1466
Tarantula Nebula
LMC
Achernar
SMC
NGC 362
VOLANS
MENSA
HYDRUS
TUCANA
GRUS
PISCIS AUSTRINUS
Gem Cluster
South Celestial Pole
47 Tucanae
CHAMAELEON
Southern Pleiades
OCTANS
INDUS
MUSCA
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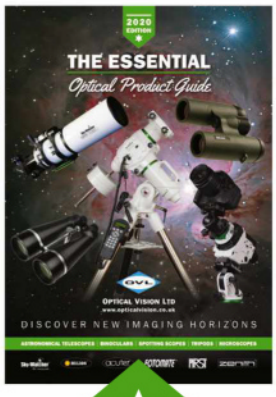

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